

## EPA REGION 6: PLANTS 11 AND 12

### Plant Operations and Sampling

Plant 11 treated water from a river in EPA Region 6 (Figure 1) and plant 12 treated water from another river basin and lake in EPA Region 6. On March 26, 2001, September 10, 2001, November 5 or 15, 2001, and February 11 or 12, 2002, plants 11 and 12 were sampled.

Plant 11 operated a chlorine dioxide plant (Figure 2):

- Ferric sulfate [ $\text{Fe}_2(\text{SO}_4)_3$ ] and cationic polymer were used for coagulation.
- There was up-flow solids contact flocculation/clarification and dual-media filtration.
- The disinfection strategy used a combination of free chlorine and chlorine dioxide to achieve disinfection requirements through the plant clearwell.
- In March 2001, chlorine dioxide was only added post-filtration, in September 2001 and February 2002 chlorine dioxide was added to the clarified water and post-filtration, and in November 2001 chlorine dioxide was added before the clarifier and after the filters (after the sampling point for the clearwell influent).
- The free chlorine residual was quenched with ammonia to form a chloramine residual prior to the storage tank and distribution.

At plant 12 (Figure 3):

- Alum was used for coagulation.
- There was dual-media filtration. (They were in the process of scrapping the granular activated carbon [GAC] filter media and going back to dual media.)
- The disinfection strategy used a combination of chlorine and ammonia to form chloramines. In February 2002, they used chlorine dioxide during pre-treatment. (They did not use chlorine dioxide as part of their treatment process in March, September, and November 2001.)

Plant 11 was sampled at the following locations:

- (1) raw water
- (2) filter influent
- (3) filter effluent or clearwell influent
- (4) clearwell effluent (not sampled in November 2001 and February 2002)
- (5) the plant effluent

In addition, the distribution system was sampled at two locations, one representing an average detention time and the other representing a maximum detention time. Furthermore, plant effluent was collected, and simulated distribution system (SDS) testing conducted with a 24- and a 48-hr holding time to represent the average and maximum detention times, respectively, in March 2001, September 2001, and February 2002. In November 2001, the SDS tests were conducted with holding times of 36 and 72 hr, respectively.

However, the plant 11 SDS samples that were shipped on September 12, 2001 were not delivered to Metropolitan Water District of Southern California (MWDSC) until September 17, 2001, since Federal Express could not use air delivery at that time. Because the samples were

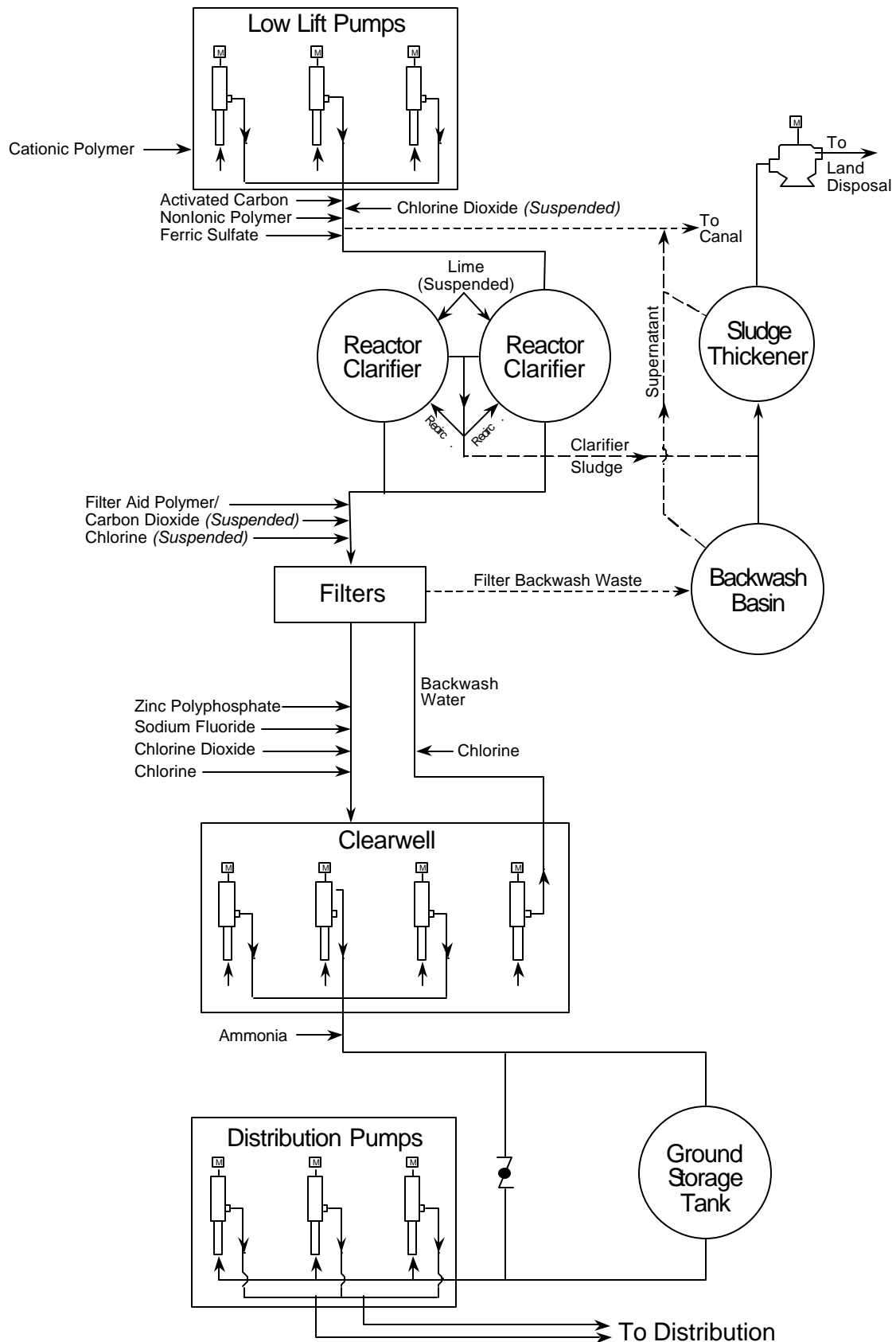
not kept cold for that entire period of time, the SDS samples for the September 2001 sampling represent a test of the long-term stability of the DBPs when held at room temperature.

**Figure 1. EPA Region 6**

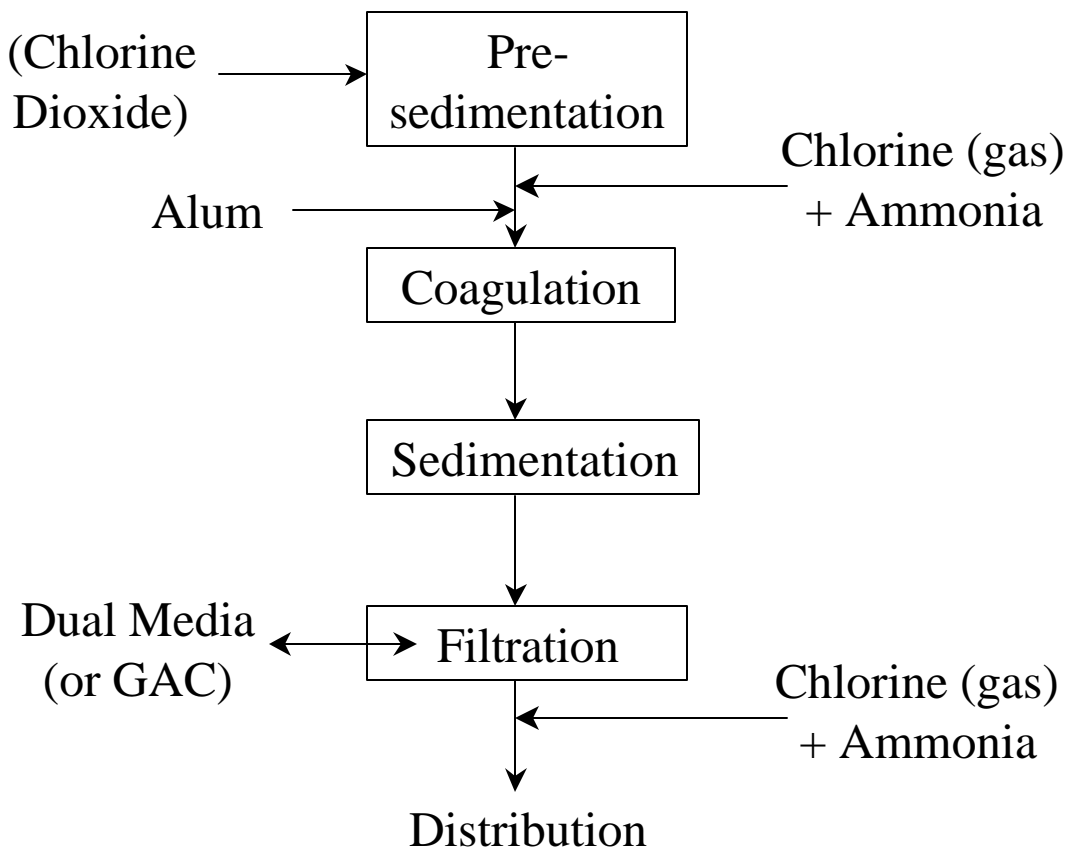


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**Figure 2. Plant 11 schematic**



**Figure 3. Plant 12 schematic**



Plant 12 was sampled at the following locations:

- (1) raw water,
- (2) after pre-treatment,
- (3) filter influent,
- (4) filter effluent,
- (5) and the plant effluent.

In addition, the distribution system was sampled at two locations, one representing an average detention time and the other representing a maximum detention time. In March 2001, plant effluent was collected and SDS testing was conducted with a 18- and a 30-hr holding time to represent the average and maximum detention times, respectively. SDS testing was not performed in September 2001. In November 2001, the SDS tests were conducted with holding times of 24 and 48 hr, respectively. In February 2002, the SDS samples were held for less than one day (holding times are not available). On the day of sampling, information was collected on the operations at each plant (Tables 1-2).

**Table 1. Operational information at plant 11**

Parameter	3/26/01	9/10/01	11/5/01	2/11/02
Plant flow (mgd)	12.96	37.4	31.7	28.8
Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> dose (mg/L)	18.7	7.6	8.5	10.4
Polymer (coagulant aid) dose (mg/L)	3.9	2.7	2.4	7.1
Polymer (filter aid) dose (mg/L)	0.024	0.048	0.048	0.048
Chlorine dioxide dose before clarifier (mg/L as ClO <sub>2</sub> )	0	0	0.35	0
Chlorine dioxide dose at clarifier (mg/L as ClO <sub>2</sub> )	0	0.35	0	0.25
Chlorine dioxide dose post-filtration (mg/L as ClO <sub>2</sub> )	0.75	0.5	0.5	0.5
Chlorine dose at filter effluent (mg/L as Cl <sub>2</sub> )	4.5	4.1	4.1	4.0
Ammonia dose at clearwell effluent (mg/L as NH <sub>3</sub> -N)	1.25	1.15	1.15	0.86

**Table 2. Operational information at plant 12**

Parameter	3/26/01	9/10/01	11/15/01	2/12/02
Plant flow (mgd)	72	64	60	60
Coagulant dose used for pre-treatment (mg/L)	0	0	0	0
Chlorine dioxide dose (mg/L as ClO <sub>2</sub> )	0	0	0	1.0
Potassium permanganate (KMnO <sub>4</sub> ) dose used for pre-treatment (mg/L)	NA <sup>a</sup>	1	1.0	1.0
Chlorine dose after pre-treatment (mg/L as Cl <sub>2</sub> )	4.6	6.0	6.5	5.0
Ammonia dose after pre-treatment (mg/L as NH <sub>3</sub> -N)	0.72	1.5	1.2	0.82
Aluminum sulfate dose used in sed. basins (mg/L)	80	95	80	80
No. filters contained GAC, contained dual media	8, 9	0, all	0, 22	0, 22
Chlorine dose at filter effluent (mg/L as Cl <sub>2</sub> )	5.5	4.8	3.3	2.4
Ammonia dose at filter effluent (mg/L as NH <sub>3</sub> -N)	0.71	1.2	0.61	0.44

<sup>a</sup>NA = Not available

## Water Quality

On the day of sampling, information was collected on water quality at each plant (Tables 3-4). Additional data were collected for total organic carbon (TOC) and ultraviolet (UV) absorbance (Tables 5-6). At plant 12, the raw water equaled a blend from two lakes. The blend ratio changed from day to day. Water after pre-treatment equaled a blend of raw and pre-treated (KMnO<sub>4</sub>) water. The detention time in the pre-sedimentation basin lead to a mixture of current and previous blends. Thus, the difference in water quality between the raw and pre-treated water at plant 12 represented, in part, changes in the blend ratio.

At plant 12 in March 2001, September 2001, November 2001, and February 2002, the water after pre-treatment had 2-19 % less TOC than the raw water, and coagulation subsequently removed 21-40 % of the remaining TOC in the pre-treated water. The water after pre-treatment had a 13-28 % reduction in UV, and coagulation reduced the UV of the pre-treated water by an additional 38-54 %. At plant 11 in March 2001, September 2001, November 2001, and February 2002, coagulation and filtration cumulatively removed 17-30 % of the TOC and reduced the UV by 23-65 %.

**Table 3. Water quality information at plant 11**

	pH				Temperature (°C)				Disinfectant Residual <sup>a</sup> (mg/L)			
Location	3/26/01	9/10/01	11/5/01	2/11/02	3/26/01	9/10/01	11/5/01	2/11/02	3/26/01	9/10/01	11/5/01	2/11/02
Raw water	8.14	8.12	8.33	NA	19.2	26.2	21.2	11.2	---	---	---	---
Filter influent	7.54	7.86	8.13	7.98	19.0	26.8	21.3	11.6	---	<b>0.31</b>	---	---
Filter eff. or clear. inf.	7.65	7.38	7.47	7.49	19.0	26.4	22.3	11.4	---	3.3	---	<b>0.17/</b> 3.7
Clearwell effluent	7.30	7.48	NS <sup>b</sup>	NS	18.0	27.8	NS	NS	<b>0.31/</b> 2.5	2.6	NS	NS
Plant effluent	7.40	7.52	7.52	7.47	18.2	24.8	21.9	11.4	<b>0.02/</b> 2.7	3.0	<b>0.10/</b> 2.9	<b>0.13/</b> 3.2
Dist. system/average	7.52	7.62	7.62	7.62	19.3	27.6	23.3	12.1	2.6	2.6	2.7	2.7
Dist. system/maximum	7.44	7.58	7.68	7.68	20.2	27.8	22.9	12.3	2.5	2.5	2.4	2.5
SDS/average	7.63	7.53	7.52	7.53	20.0	26.0	21.4	13.9	2.7	2.4	2.5	2.8
SDS/maximum	7.52	7.57	7.56	7.52	18.1	25.8	21.6	14.1	2.5	2.3	2.2	2.7

<sup>a</sup>Chlorine dioxide residuals (values shown in bold) in clearwell effluent and plant effluent in March 2001, in filter influent in September 2001, in plant effluent in November 2001, and in clearwell influent and in plant effluent in February 2002; chlorine residuals (values shown in italics) in clearwell influent in September 2001 and in February 2002; chloramine residuals at other locations.

<sup>b</sup>NS = Not sampled

**Table 4. Water quality information at plant 12**

	pH				Temperature (°C)				Disinfectant Residual <sup>a</sup> (mg/L)			
Location	3/26/01	9/10/01	11/15/01	2/12/02	3/26/01	9/10/01	11/15/01	2/12/02	3/26/01	9/10/01	11/15/01	2/12/02
Raw water	8.3	7.7	7.6	7.8	20.9	28	23.6	16	---	---	---	---
After pre-treatment	8.4	7.8	8.0	7.8	19.9	28	23.4	14	---	---	---	<b>0.15</b>
Filter influent	8.8	8.3	8.1	8.4	19.0	27	24.1	17	2.1	1.6	2.3	1.7
Filter effluent	8.2	7.6	NA	8.1	20.8	27	23.1	16	1.6	4.8	2.1	1.4
Plant effluent	8.1	7.6	8.3	7.6	20.8	27	23.4	14	4.9	4.7	4.3	4.6
Dist. system/average	7.8	7.7	NA	7.4	15.4	26	NA	16	3.6	3.2	NA	NA
Dist. system/maximum	7.7	7.7	NA	7.4	21.3	25	NA	18	2.2	2.6	NA	NA
SDS/average	NA	NS <sup>b</sup>	7.3	7.4	NA	NS	25	16	NA	NS	3.4	2.7
SDS/maximum	NA	NS	7.3	7.4	NA	NS	25	18	NA	NS	2.8	2.4

<sup>a</sup>Chlorine dioxide residual (value shown in bold) at pre-treatment sample location in February 2002; chloramine residuals at other locations.

<sup>b</sup>NS = Not sampled

**Table 5. TOC and UV removal at plant 11**

Location	TOC (mg/L)	UV <sup>a</sup> (cm <sup>-1</sup> )	SUVA <sup>b</sup> (L/mg-m)	Removal/Unit (%)		Removal/Cumulative (%)	
				TOC	UV	TOC	UV
03/26/2001							
Raw	5.66	0.137	2.42	---	---	---	---
Filter Inf.	4.08	0.083	2.03	28%	39%	28%	39%
Filter Eff.	4.24	0.089	2.10	-3.9%	-7.2%	25%	35%
09/10/2001							
Raw	3.51	0.079	2.25	---	---	---	---
Filter Inf.	3.24	0.069	2.13	7.7%	13%	7.7%	13%
Clearwell Inf.	2.89	0.044	1.52	11%	36%	18%	44%
11/5/2001							
Raw	4.68	0.115	2.46	---	---	---	---
Filter Inf.	4.0	0.094	2.35	15%	18%	15%	18%
Clearwell Inf.	3.87	0.088	2.27	3.3%	6.4%	17%	23%
02/11/2002							
Raw	4.26	0.108	2.54	---	---	---	---
Filter Inf.	3.25	0.055	1.69	24%	49%	24%	49%
Clearwell Inf.	3.0	0.038	1.27	7.7%	31%	30%	65%

<sup>a</sup>UV = Ultraviolet absorbance reported in units of "inverse centimeters" (APHA, 1998)

<sup>b</sup>SUVA (L/mg-m) = Specific ultraviolet absorbance =  $100 \times \text{UV (cm}^{-1}\text{)} / \text{DOC (mg/L)}$  or  $\text{UV (m}^{-1}\text{)} / \text{DOC (mg/L)}$ , where DOC = dissolved organic carbon, which typically = 90-95% TOC (used TOC values in calculating SUVA) (e.g.,  $\text{UV} = 0.137/\text{cm} = 0.137/(0.01 \text{ m}) = 13.7/\text{m}$ ,  $\text{DOC} = 5.66 \text{ mg/L}$ ,  $\text{SUVA} = (13.7 \text{ m}^{-1})/(5.66 \text{ mg/L}) = 2.42 \text{ L/mg-m}$ )

**Table 6. TOC and UV removal at plant 12**

Location	TOC (mg/L)	UV <sup>a</sup> (cm <sup>-1</sup> )	SUVA <sup>b</sup> (L/mg-m)	Removal/Unit (%)		Removal/Cumulative (%)	
				TOC	UV	TOC	UV
03/26/2001							
Raw	6.72	0.184	2.74	---	---	---	---
After Pre-Treat.	6.12	0.160	2.61	8.9%	13%	8.9%	13%
Filter Inf.	4.48	0.095	2.12	27%	41%	33%	48%
Filter Eff.	4.52	0.086	1.90	-0.9%	9.5%	33%	53%
09/10/2001							
Raw	7.52	0.273	3.63	---	---	---	---
After Pre-Treat.	6.20	0.196	3.16	18%	28%	18%	28%
Filter Inf.	3.70	0.091	2.46	40%	54%	51%	67%
Filter Eff.	3.80	0.089	2.34	-2.7%	2.2%	49%	67%
11/15/2001							
Raw	7.01	0.233	3.32	---	---	---	---
After Pre-Treat.	5.71	0.188	3.29	19%	19%	19%	19%
Filter Inf.	4.51	0.117	2.59	21%	38%	36%	50%
Filter Eff.	4.42	0.115	2.60	2.0%	1.7%	37%	51%
02/12/2002							
Raw	5.33	0.176	3.30	---	---	---	---
After Pre-Treat.	5.24	0.129	2.46	1.7%	27%	1.7%	27%
Filter Inf.	3.30	0.070	2.12	37%	46%	38%	60%
Filter Eff.	3.21	0.069	2.15	2.7%	1.4%	40%	61%

<sup>a</sup>UV = Ultraviolet absorbance reported in units of "inverse centimeters" (APHA, 1998)

<sup>b</sup>SUVA (L/mg-m) = Specific ultraviolet absorbance =  $100 \times \text{UV (cm}^{-1}\text{)} / \text{DOC (mg/L)}$  or  $\text{UV (m}^{-1}\text{)} / \text{DOC (mg/L)}$ , where DOC = dissolved organic carbon, which typically = 90-95% TOC (used TOC values in calculating SUVA) (e.g.,  $\text{UV} = 0.184/\text{cm} = 0.184/(0.01 \text{ m}) = 18.4/\text{m}$ ,  $\text{DOC} = 6.72 \text{ mg/L}$ ,  $\text{SUVA} = (18.4 \text{ m}^{-1})/(6.72 \text{ mg/L}) = 2.74 \text{ L/mg-m}$ )

Table 7 shows the values of miscellaneous other water quality parameters in the raw waters at the two EPA Region 6 plants.

**Table 7. Miscellaneous water quality parameters in raw water at the EPA Region 6 plants**

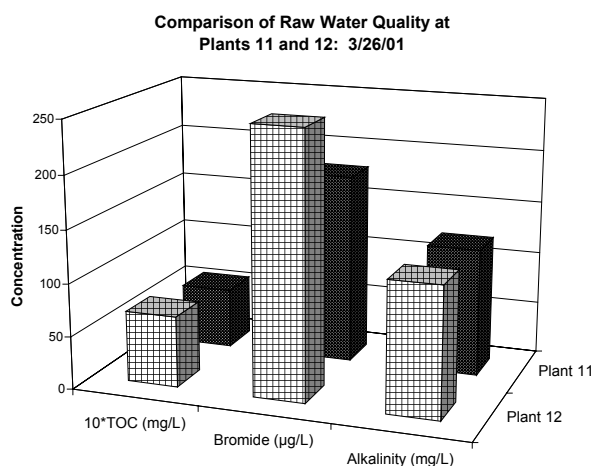
Plant 11			
Date	Bromide (mg/L)	Alkalinity (mg/L)	Ammonia (mg/L as N)
03/26/2001	0.18	121	ND
09/10/2001	0.21	117	0.15
11/5/2001	0.16	133	ND
02/11/2002	0.18	153	ND

Plant 12			
Date	Bromide (mg/L)	Alkalinity (mg/L)	Ammonia (mg/L as N)
03/26/2001	0.25	123	ND
09/10/2001	0.02	54	0.04
11/15/2001	0.15	70	ND
02/12/2002 <sup>a</sup>	0.33	111	ND

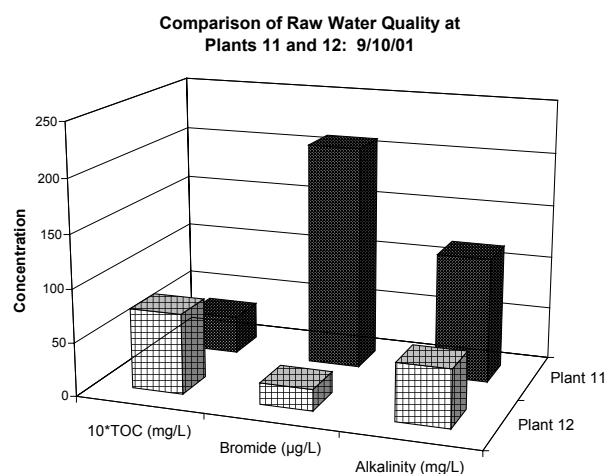
<sup>a</sup>Bromide sampled at pre-treatment sample location in February 2002

Both EPA Region 6 plants treated waters high in TOC, bromide, and alkalinity in March 2001, November 2001, and February 2002 (Tables 5-7, Figure 4). However, in September 2001, the water qualities were quite different (Table 5-7, Figure 5): the TOC at plant 11 was lower, whereas the bromide and alkalinity at plant 12 was lower.

**Figure 4**



**Figure 5**



At plant 12, the bromide and alkalinity on September 10, 2001 were significantly lower than on March 26, 2001, whereas the TOC was only slightly higher. This could either reflect a different blend of source waters on the two sampling dates or some seasonal variation in water quality. For example, a storm event can result in an increase in TOC due to runoff and a dilution of inorganic parameters such as bromide and alkalinity.

## DBPs

*Oxyhalides.* Tables 8-9 show the formation of oxyhalides at the two plants. Chlorine dioxide will typically not react with bromide to form bromate, as was observed at plant 11 (Table 8) and plant 12 in February 2002 (Table 9).



**Table 8. Oxyhalide formation at plant 11**

Location	Bromate <sup>a</sup> (µg/L)	Chlorite <sup>a</sup> (µg/L)	Chlorate <sup>a</sup> (µg/L)	ClO <sub>2</sub> <sup>-</sup> /ClO <sub>2</sub> <sup>b</sup> %
03/26/2001				
Filter Eff.	ND	ND	ND	---
Clearwell Eff.	ND	639	244	85%
09/10/2001				
Clearwell Inf.	ND	399	94	47%
Clearwell Eff.	ND	406	160	48%
11/5/2001				
Filter Inf.	ND	238	47	68%
Clearwell Inf.	ND	202	47	58%
Plant Eff.	ND	478	159	56%
02/11/2002				
Filter Inf.	ND	135	36	54%
Clearwell Inf.	ND	212	289	28%
Plant Eff.	ND	420	167	56%

<sup>a</sup>Reporting detection level for bromate = 3 µg/L and for chlorate and chlorite = 5 µg/L

<sup>b</sup>Chlorine dioxide dose in March 2001 = 0.75 mg/L

Chlorine dioxide dose in September 2001 = 0.35 mg/L at clarifier and 0.5 mg/L at post

Chlorine dioxide dose in November 2001 = 0.35 mg/L before clarifier and 0.5 mg/L at post

Chlorine dioxide dose in February 2002 = 0.25 mg/L at clarifier and 0.5 mg/L at post

**Table 9. Oxyhalide formation at plant 12**

Location	Bromate (µg/L)	Chlorite (µg/L)	Chlorate (µg/L)	ClO <sub>2</sub> <sup>-</sup> /ClO <sub>2</sub> <sup>a</sup> %
03/26/2001				
After Pre-Treat.	ND	ND	8.6	---
Filter Inf.	ND	ND	30	---
Filter Eff.	ND	ND	32	---
09/10/2001				
After Pre-Treat.	ND	ND	ND	---
Filter Inf.	ND	ND	ND	---
Filter Eff.	ND	ND	ND	---
11/15/2001				
After Pre-Treat.	ND	ND	ND	---
Filter Inf.	ND	ND	ND	---
Filter Eff.	ND	ND	ND	---
02/12/2002				
After Pre-Treat.	ND	900	94	90%
Filter Inf.	ND	648	182	65%
Filter Eff.	ND	634	169	63%

<sup>a</sup>Chlorine dioxide dose in February 2002 = 1.0 mg/L

It has been reported that during water treatment, approximately 50-70 % of the chlorine dioxide ( $\text{ClO}_2$ ) reacted will immediately appear as chlorite ( $\text{ClO}_2^-$ ) and the remainder as chloride (Aieta and Berg, 1986). At plant 11, a similar percentage was observed in November 2001 and for most of the samples collected in February 2002, whereas a somewhat higher amount of chlorite was detected in March 2001 and a somewhat lower level was detected in September 2001 (Table 8). Likewise, a similar percentage to that reported by Aieta and Berg (1986) was observed for most of the samples collected in February 2002 at plant 12 (Table 9).

Because chlorine dioxide was not used at plant 12 on March 26, 2001, September 10, 2001, or November 15, 2001, no chlorite was detected (Table 9). However, a very low amount of chlorate was found in the water in March 2001, even before the addition of chlorine (Table 9). In other research, low levels of chlorate have been detected in raw water samples (Bolyard et al., 1992).

*Organic DBPs.* Tables 10 and 11 (3/26/01), Tables 13 and 14 (9/10/01), Tables 19 and 20 (11/5/01 and 11/15/01), and Tables 22 and 23 (2/11/02 and 2/12/02) show results for the halogenated organic DBPs that were analyzed by MWDSC. Table 12 (3/26/01 [plant 11]) and Table 21 (11/15/01 [plant 12]) shows results from broadscreen DBP analyses conducted at the U.S. Environmental Protection Agency (USEPA). Tables 15 and 16 (9/10/01), and Tables 24 and 25 (2/11/02 and 2/12/02) show results for additional target DBPs that were analyzed for at the University of North Carolina (UNC). Tables 17 and 18 (9/10/01), and Tables 26 and 27 (2/11/02 and 2/12/02) show results for halogenated furanones that were analyzed at UNC.

#### Summary of tables for organic DBPs

DBP Analyses (Laboratory)	3/26/01	9/10/01	11/5/01 and 11/15/01	2/11/02 and 2/12/02
Halogenated organic DBPs (MWDSC)	Tables 10- 11	Tables 13-14	Tables 19-20	Tables 22-23
Additional target DBPs (UNC)		Tables 15-16		Tables 24-25
Halogenated furanones (UNC)		Tables 17-18		Table 26-27
Broadscreen analysis (USEPA)	Table 12 <sup>a</sup>		Table 21 <sup>b</sup>	

<sup>a</sup>Plant 11

<sup>b</sup>Plant 12

**Table 10. DBP results at plant 11 (3/26/01)**

03/26/2001	MRL <sup>a</sup>	Plant 11 <sup>b</sup>							
Compound	µg/L	Raw	Filt Eff	Clearwell	Plant Eff	DS/Ave	DS/Max	SDS/Ave	SDS/Max
Halomethanes									
Chloromethane	0.15	ND <sup>c</sup>		ND	ND	ND		0.35	
Bromomethane	0.20	ND		ND	ND	ND		ND	
Bromochloromethane	0.14	ND		ND	ND	ND		ND	
Dibromomethane	0.11	ND		ND	ND	ND		ND	
Chloroform <sup>d</sup>	0.1	ND	0.2	8	6	6	6	7	7
Bromodichloromethane <sup>d</sup>	0.1	ND	0.4	19	15	15	17	17	17
Dibromochloromethane <sup>d</sup>	0.10	ND	0.4	23	19	18	21	20	20
Bromoform <sup>d</sup>	0.12	ND	ND	7	6	6	5	6	6
THM4 <sup>e</sup>		ND	1.0	57	46	45	49	50	50
Dichloroiodomethane	0.2	ND	ND	0.3	ND	0.2	ND	ND	ND
Bromochloroiodomethane	0.20	ND	ND	0.3	ND	0.2	ND	0.2	ND
Dibromoiodomethane	0.60	ND	ND	ND	ND	ND	ND	ND	ND
Chlorodiiodomethane	0.51	ND	ND	ND	ND	ND	ND	ND	ND
Bromodiiodomethane	0.56	ND	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.54	ND	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.06	ND		0.2	0.15	ND		ND	
Tribromochloromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND
Haloacetic acids									
Monochloroacetic acid <sup>d</sup>	2		ND	ND	ND	ND		2.7	
Monobromoacetic acid <sup>d</sup>	1		ND	ND	ND	ND		ND	
Dichloroacetic acid <sup>d</sup>	1		ND	10	9.7	11		12	
Bromochloroacetic acid <sup>d</sup>	1		ND	12	11	13		13	
Dibromoacetic acid <sup>d</sup>	1		ND	8.7	8.1	8.9		9.2	
Trichloroacetic acid <sup>d</sup>	1		ND	4.5	3.8	5.1		5.4	
Bromodichloroacetic acid	1		ND	10	9.0	11		11	
Dibromochloroacetic acid	1		ND	8.8	7.5	8.9		9.2	
Tribromoacetic acid	2		ND	ND	ND	ND		ND	
HAA5 <sup>f</sup>			ND	23	22	25		29	
HAA9 <sup>g</sup>			ND	54	49	58		63	
DXAA <sup>h</sup>			ND	31	29	33		34	
TXAA <sup>i</sup>			ND	23	20	25		26	
Haloacetonitriles									
Chloroacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile <sup>d</sup>	0.10	ND	ND	0.3	2	2	2	2	2
Bromochloroacetonitrile <sup>d</sup>	0.1	ND	ND	0.4	3	3	3	3	3
Dibromoacetonitrile <sup>d</sup>	0.17	ND	ND	0.6	3	4	4	4	4
Trichloroacetonitrile <sup>d</sup>	0.1	ND	ND	ND	ND	ND	ND	ND	ND
Haloacetaldehydes									
Dichloroacetaldehyde	0.16	ND	ND	1	0.4	0.8	1	0.8	1
Bromochloroacetaldehyde	0.1	0.1	ND	0.6	0.3	0.4	0.8	0.4	0.4
Chloral hydrate <sup>d</sup>	0.1	0.2	ND	0.3	0.5	0.6	1	0.7	0.6
Tribromoacetaldehyde	0.1	ND	ND	ND	ND	ND	0.5	ND	ND

Table 10 (continued)

03/26/2001	MRL <sup>a</sup>	Plant 11 <sup>b</sup>							
Compound	µg/L	Raw	Filt Eff	Clearwell	Plant Eff	DS/Ave	DS/Max	SDS/Ave	SDS/Max
Haloketones									
Chloropropanone	0.5	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloropropanone <sup>d</sup>	0.11	ND	ND	1	0.3	0.4	0.3	0.4	0.5
1,3-Dichloropropanone	0.10	ND	ND	ND	ND	ND	0.5	ND	ND
1,1-Dibromopropanone	3	ND		ND	ND	ND		ND	
1,3-Dibromopropanone	3	ND		ND	ND	ND		ND	
1,1,1-Trichloropropanone <sup>d</sup>	0.10	ND	ND	ND	0.8	0.4	1	0.6	0.4
1,1,3-Trichloropropanone	0.11	ND	ND	ND	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	3	ND		ND	<1 <sup>j</sup>	ND		ND	
1,1,1-Tribromopropanone	3	ND		ND	ND	ND		ND	
1,1,3-Tribromopropanone	3	ND		ND	ND	ND		ND	
1,1,3,3-Tetrachloropropanone	0.12	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1,3-Tetrachloropropanone	3	ND		ND	ND	ND		ND	
1,1,3,3-Tetrabromopropanone	0.5	ND	ND	ND	ND	ND	ND	ND	ND
Halonitromethanes									
Bromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	3	ND		ND	<1	<1		<1	
Bromochloronitromethane	3	ND		ND	<1	<1		<1	
Dibromonitromethane	0.12	ND	ND	0.2	0.4	ND	0.2	ND	ND
Chloropicrin <sup>d</sup>	0.1	ND	ND	ND	ND	0.4	0.1	0.2	0.4
Miscellaneous Compounds									
Methyl ethyl ketone	1.90	ND		ND	ND	ND		ND	
Methyl <i>tertiary</i> butyl ether	0.16	ND		ND	ND	ND		ND	
Benzyl chloride	2	ND	ND	ND	ND	ND	ND	ND	ND

<sup>a</sup>MRL = Minimum reporting level, which equals method detection limit (MDL) or lowest calibration standard or concentration of blank

<sup>b</sup>Plant 11 sampled at (1) raw water, (2) filter effluent, (3) clearwell effluent, (4) plant effluent, distribution system (DS) at (5) average and (6) maximum detention times, and SDS testing of plant effluent at (7) average and (8) maximum detention times

<sup>c</sup>ND = Not detected at or above MRL

<sup>d</sup>DBP in the Information Collection Rule (ICR) (note: some utilities collected data for all 9 haloacetic acids for the ICR, but monitoring for only 6 haloacetic acids was required)

<sup>e</sup>THM4 = Sum of 4 THMs (chloroform, bromodichloromethane, dibromochloromethane, bromoform)

<sup>f</sup>HAA5 = Sum of 5 haloacetic acids (monochloro-, monobromo-, dichloro-, dibromo-, trichloroacetic acid)

<sup>g</sup>HAA9 = Sum of 9 haloacetic acids

<sup>h</sup>DXAA = Sum of dihaloacetic acids (dichloro-, bromochloro-, dibromoacetic acid)

<sup>i</sup>TXAA = Sum of trihaloacetic acids (trichloro-, bromodichloro-, dibromochloro-, tribromoacetic acid)

<sup>j</sup><1: Concentration less than lowest calibration standard (i.e., 1 µg/L)

**Table 11. DBP results at plant 12 (3/26/01)**

03/26/2001	MRL <sup>a</sup>	Plant 12 <sup>k</sup>								
Compound	µg/L	Raw	Pre-Treat	Filt Inf	Filt Eff	Plant Eff	DS/Ave	DS/Max	SDS/Ave	SDS/Max
Halomethanes										
Chloromethane	0.15	ND <sup>c</sup>		ND		ND	ND		ND	
Bromomethane	0.20	ND		ND		ND	ND		ND	
Bromochloromethane	0.14	ND		ND		ND	ND		ND	
Dibromomethane	0.11	ND		ND		ND	ND		ND	
Chloroform <sup>d</sup>	0.1	ND	0.2	6	5	5	6	6	5	7
Bromodichloromethane <sup>d</sup>	0.1	ND	ND	11	10	11	14	17	12	15
Dibromochloromethane <sup>d</sup>	0.10	ND	0.4	8	8	10	18	30	12	16
Bromoform <sup>d</sup>	0.12	ND	ND	5	7	8	14	31	9	11
THM4 <sup>e</sup>		ND	0.6	30	30	34	52	84	38	49
Dichloroiodomethane	0.2	ND	ND	3	NR <sup>l</sup>	4	4	NR	4	NR
Bromochloroiodomethane	0.20	ND	ND	3	NR	3	6	NR	3	2
Dibromoiodomethane	0.60	ND	ND	2	2	3	7	0.8	4	4
Chlorodiiodomethane	0.51	ND	ND	2	1	2	3	ND	3	2
Bromodiiodomethane	0.56	ND	ND	ND	ND	0.3	1	ND	0.4	ND
Iodoform	0.54	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.06	ND		ND		ND	ND		ND	
Tribromochloromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Haloacetic acids										
Monochloroacetic acid <sup>d</sup>	2		ND	ND	ND	ND	ND		2.0	
Monobromoacetic acid <sup>d</sup>	1		ND	ND	ND	ND	ND		ND	
Dichloroacetic acid <sup>d</sup>	1		ND	11	12	14	12		14	
Bromochloroacetic acid <sup>d</sup>	1		ND	10	12	15	15		14	
Dibromoacetic acid <sup>d</sup>	1		ND	6.9	7.7	12	14		12	
Trichloroacetic acid <sup>d</sup>	1		ND	2.4	4.1	5.1	3.5		5.1	
Bromodichloroacetic acid	1		ND	2.1	4.8	6.0	5.2		5.8	
Dibromochloroacetic acid	1		ND	1.5	3.4	3.9	4.1		3.7	
Tribromoacetic acid	2		ND	ND	ND	ND	ND		ND	
HAA5 <sup>f</sup>			ND	20	24	31	30		33	
HAA9 <sup>g</sup>			ND	34	44	56	54		57	
DXAA <sup>h</sup>			ND	28	32	41	41		40	
TXAA <sup>i</sup>			ND	6.0	12	15	13		15	
Haloacetonitriles										
Chloroacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile <sup>d</sup>	0.10	ND	ND	0.8	0.7	1	2	1	2	2
Bromochloroacetonitrile <sup>d</sup>	0.1	ND	ND	1	1	2	2	3	2	2
Dibromoacetonitrile <sup>d</sup>	0.17	ND	ND	0.6	0.6	1	3	4	2	2
Trichloroacetonitrile <sup>d</sup>	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Haloacetaldehydes										
Dichloroacetaldehyde	0.16	ND	ND	1	0.5	0.6	0.6	0.3	0.7	0.8
Bromochloroacetaldehyde	0.1	ND	ND	0.9	0.4	0.6	0.9	0.6	0.8	0.9
Chloral hydrate <sup>d</sup>	0.1	0.1	ND	0.8	0.2	0.2	0.4	0.2	0.3	0.3
Tribromoacetaldehyde	0.1	ND	ND	0.6	ND	0.2	0.2	0.2	0.3	0.2

Table 11 (continued)

03/26/2001	MRL <sup>a</sup>	Plant 12 <sup>b</sup>								
Compound	µg/L	Raw	Pre-Treat	Filt Inf	Filt Eff	Plant Eff	DS/Ave	DS/Max	SDS/Ave	SDS/Max
Haloketones										
Chloropropanone	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloropropanone <sup>d</sup>	0.11	ND	ND	0.4	0.3	0.3	ND	ND	0.3	0.3
1,3-Dichloropropanone	0.10	ND	ND	0.3	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	3	ND		ND		ND	ND		ND	
1,3-Dibromopropanone	3	ND		ND		ND	ND		ND	
1,1,1-Trichloropropanone <sup>d</sup>	0.10	ND	ND	0.3	0.2	0.3	0.2	ND	0.3	0.3
1,1,3-Trichloropropanone	0.11	ND	ND	ND	ND	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	3	ND		<1 <sup>j</sup>		<1	ND		<1	
1,1,1-Tribromopropanone	3	ND		ND		ND	ND		ND	
1,1,3-Tribromopropanone	3	ND		ND		ND	ND		ND	
1,1,3,3-Tetrachloropropanone	0.12	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1,3-Tetrachloropropanone	3	ND		ND		ND	ND		ND	
1,1,3,3-Tetrabromopropanone	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
Halonitromethanes										
Bromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	3	ND		<1		<1	<1		<1	
Bromochloronitromethane	3	ND		<1		<1	<1		<1	
Dibromonitromethane	0.12	ND	ND	0.1	ND	0.3	0.4	0.8	0.3	0.2
Chloropicrin <sup>d</sup>	0.1	ND	ND	0.1	0.1	0.2	0.2	0.1	0.2	0.4
Miscellaneous Compounds										
Methyl ethyl ketone	1.90	ND		ND		ND	ND		ND	
Methyl <i>tertiary</i> butyl ether	0.16	ND		ND		ND	ND		ND	
Benzyl chloride	2	ND	ND	ND	ND	ND	ND	ND	ND	ND

<sup>k</sup>Plant 12 sampled at (1) raw water, (2) after pre-treatment, (3) filter influent, (4) filter effluent,

(5) plant effluent, DS at (6) average and (7) maximum detention times, and

SDS testing of plant effluent at (8) average and (9) maximum detention times

<sup>j</sup>NR = Not reported, due to interference problem on gas chromatograph or to problem with quality assurance

**Table 12. Occurrence of other DBPs<sup>a</sup> at plant 11: plant effluent (3/26/01)**

<u>Halomethanes</u> <i>Dibromochloromethane<sup>b</sup></i> <i>Bromoform</i> <i>Dichloriodomethane</i> <i>Bromochloriodomethane</i> <i>Dibromiodomethane</i>	<u>Haloketones</u> 1,1-Dichloropropanone 1,1,1-Trichloropropanone 1,1,3-Trichloropropanone 1-Bromo-1,1-dichloropropanone <i>1,1-Dibromo-3-chloropropanone</i> <i>1,1,3-Tribromopropanone</i> 1-Bromo-1,3,3-trichloropropanone <i>1,3-Dibromo-1,3-dichloropropanone</i> <i>1,1,3-Tribromo-3-chloropropanone</i> <i>1,1,3,3-Tetrabromopropanone</i>
<u>Haloacids</u> <i>Dichloroacetic acid</i> <i>Bromochloroacetic acid</i> <i>Dibromoacetic acid</i> <i>Bromodichloroacetic acid</i> <i>Tribromoacetic acid</i> <i>2,2-Dibromopropanoic acid</i> Dibromochloropropanoic acid <sup>c</sup> <i>3,3-Dibromopropenoic acid</i> Bromochloro-4-oxopentanoic acid <sup>c</sup> <i>3,3-Dibromo-4-oxopentanoic acid</i> Bromoheptanoic acid <sup>c</sup> Bromochloroheptanoic acid <sup>c</sup> (2 isomers) Dibromoheptanoic acid <sup>c</sup> Bromochlorononanoic acid <sup>c</sup> 2-(4-Chloro-2-methylphenoxy)-propanoic acid <i>cis-2-Bromo-3-methylbutenedioic acid</i>	<u>Haloacetonitriles</u> <i>Bromochloroacetonitrile</i> <i>Dibromoacetonitrile</i> Dibromochloroacetonitrile <i>Tribromoacetonitrile</i>
	<u>Haloaldehydes</u> Bromochloroacetaldehyde Dibromoacetaldehyde Bromodichloroacetaldehyde 2-Bromo-2-methylpropanal
	<u>Halonitromethanes</u> <i>Dichloronitromethane</i>
	<u>Non-halogenated DBPs</u> <i>Octadecanoic acid</i>

<sup>a</sup>DBPs detected by broadscreen gas chromatography/mass spectrometry (GC/MS) technique.

<sup>b</sup>Compounds listed in italics were confirmed through the analysis of authentic standards; haloacids and non-halogenated carboxylic acids identified as their methyl esters.

<sup>c</sup>Exact isomer not known

**Table 13. DBP results at plant 11 (9/10/01)**

09/10/2001	MRL <sup>a</sup>	Plant 11 <sup>b</sup>							
Compound	µg/L	Raw	Filt Eff	Clearwell	Plant Eff	DS/Ave	DS/Max	SDS/Ave	SDS/Max
Halomethanes									
Chloromethane	0.2	ND <sup>c</sup>		ND	ND	ND		ND	
Bromomethane	0.2	ND		ND	ND	ND		ND	
Bromochloromethane	0.5	ND		ND	ND	ND		ND	
Dibromomethane	0.5	ND		ND	ND	ND		ND	
Chloroform <sup>d</sup>	0.1	ND	1	3	2	4	4	1	1
Bromodichloromethane <sup>d</sup>	0.1	ND	6	16	17	21	22	16	44
Dibromochloromethane <sup>d</sup>	0.1	ND	10	24	24	26	27	24	16
Bromoform <sup>d</sup>	0.1	ND	2	6	6	8	9	5	8
THM4 <sup>e</sup>		ND	19	49	49	59	62	46	69
Dichloroiodomethane	0.5	ND	2	1	2	0.9	0.7	ND	ND
Bromochloroiodomethane	0.5	ND	ND	0.8	0.7	ND	ND	ND	ND
Dibromoiodomethane	0.25	ND	ND	0.4	0.4	ND	ND	ND	ND
Chlorodiiodomethane	0.1	ND	ND	ND	0.3	ND	ND	ND	ND
Bromodiiodomethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.1	ND	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.2	ND		ND	ND	ND		ND	
Tribromochloromethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND
Haloacetic acids									
Monochloroacetic acid <sup>d</sup>	2		ND	ND	ND	ND			
Monobromoacetic acid <sup>d</sup>	1		ND	1.4	1.4	1.2			
Dichloroacetic acid <sup>d</sup>	1		3.2	4.8	4.7	5.1			
Bromochloroacetic acid <sup>d</sup>	1		5.1	8.0	7.8	9.4			
Dibromoacetic acid <sup>d</sup>	1		8.2	9.1	9.4	8.8			
Trichloroacetic acid <sup>d</sup>	1		ND	2.2	2.0	2.3			
Bromodichloroacetic acid	1		3.1	8.1	7.6	7.8			
Dibromochloroacetic acid	1		3.2	7.6	7.2	7.1			
Tribromoacetic acid	2		ND	2.2	2.0	2.2			
HAA5 <sup>f</sup>			11	18	18	17			
HAA9 <sup>g</sup>			23	43	42	44			
DXAA <sup>h</sup>			17	22	22	23			
TXAA <sup>i</sup>			6.3	20	19	19			
Haloacetonitriles									
Chloroacetonitrile	0.1	ND	ND	0.2	ND	ND	ND	ND	ND
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	0.2	ND	ND
Dichloroacetonitrile <sup>d</sup>	0.1	ND	0.4	0.6	0.6	0.7	0.8	0.2	0.2
Bromochloroacetonitrile <sup>d</sup>	0.1	ND	0.6	1	1	1	1	2	2
Dibromoacetonitrile <sup>d</sup>	0.1	ND	0.6	2	2	2	2	NR <sup>i</sup>	NR
Trichloroacetonitrile <sup>d</sup>	0.1	ND	ND	ND	ND	ND	ND	ND	ND
Bromodichloroacetonitrile	0.5	ND		ND	ND				ND
Dibromochloroacetonitrile	0.5	ND		0.6	ND				ND
Tribromoacetonitrile	0.5	ND		ND	ND				ND
Haloacetaldehydes									
Dichloroacetaldehyde	0.22	ND	0.7	1	2	0.9	0.9	0.4	0.9
Bromochloroacetaldehyde	0.5	ND	0.6	1	0.8	0.9	0.9	0.3	0.4
Chloral hydrate <sup>d</sup>	0.1	ND	ND	1	NR	0.9	0.8	0.2	0.3
Tribromoacetaldehyde	0.1	ND	0.2	0.8	0.4	ND	ND	ND	ND



Table 13 (continued)

09/10/2001	MRL <sup>a</sup>	Plant 11 <sup>b</sup>							
Compound	µg/L	Raw	Filt Eff	Clearwell	Plant Eff	DS/Ave	DS/Max	SDS/Ave	SDS/Max
Haloketones									
Chloropropanone	0.1	ND	0.1	ND	0.1	ND	0.1	ND	ND
1,1-Dichloropropanone <sup>d</sup>	0.10	ND	0.4	0.2	0.3	0.2	0.3	0.1	0.1
1,3-Dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	0.1	ND	0.4	0.2	0.2	0.2	0.2	ND	ND
1,1,1-Trichloropropanone <sup>d</sup>	0.1	ND	0.3	0.5	0.5	0.3	0.2	ND	ND
1,1,3-Trichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	0.1	ND	0.2	0.4	0.4	ND	ND	ND	ND
1,1,1-Tribromopropanone	2.5	ND	NR	ND	ND	ND	NR	ND	NR
1,1,3-Tribromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrachloropropanone	0.1	ND	0.6	0.3	0.1	ND	ND	ND	ND
1,1,1,3-Tetrachloropropanone	0.10	ND	ND	0.5	0.1	ND	ND	ND	ND
1,1,3,3-Tetrabromopropanone	0.5	ND	ND	ND	ND	ND	ND	ND	ND
Halonitromethanes									
Bromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND
Bromochloronitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND
Dibromonitromethane	0.10	ND	ND	0.2	0.2	0.1	ND	ND	ND
Chloropicrin <sup>d</sup>	0.1	ND	ND	ND	ND	ND	0.1	ND	ND
Bromodichloronitromethane	0.5	ND		ND	ND				0.6
Dibromochloronitromethane	0.5	ND		ND	ND				0.5
Bromopicrin	0.5	ND		ND	ND				ND
Miscellaneous Compounds									
Methyl ethyl ketone	0.5	0.6		ND	ND	0.6		0.7	
Methyl <i>tertiary</i> butyl ether	0.2	ND		ND	ND	ND		ND	
Benzyl chloride	0.25	ND	NR	ND	ND	ND	NR	ND	NR
1,1,2,2-Tetrabromo-2-chloroethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND

**Table 14. DBP results at plant 12 (9/10/01)**

09/10/2001	MRL <sup>a</sup>	Plant 12 <sup>k</sup>						
Compound	µg/L	Raw	Pre-Treat	Filt Inf	Filt Eff	Plant Eff	DS/Ave	DS/Max
Halomethanes								
Chloromethane	0.2	ND <sup>c</sup>		ND		ND	ND	
Bromomethane	0.2	ND		ND		ND	ND	
Bromochloromethane	0.5	ND		ND		ND	ND	
Dibromomethane	0.5	ND		ND		ND	ND	
Chloroform <sup>d</sup>	0.1	ND	0.4	9	14	14	17	19
Bromodichloromethane <sup>d</sup>	0.2	ND	NR <sup>i</sup>	9	NR	13	15	NR
Dibromochloromethane <sup>d</sup>	0.25	ND	NR	4	NR	6	7	NR
Bromoform <sup>d</sup>	0.5	ND	ND	1	NR	1	2	NR
THM4 <sup>e</sup>		ND	NR	23	NR	34	41	NR
Dichloriodomethane	0.5	ND	NR	6	NR	7	10	NR
Bromochloriodomethane	0.5	ND	ND	1	2	2	2	2
Dibromiodomethane	0.52	ND	ND	0.6	0.8	1	1	ND
Chlorodiiodomethane	0.25	ND	NR	0.4	NR	0.5	2	NR
Bromodiiodomethane	0.25	ND	ND	ND	ND	0.3	0.6	ND
Iodoform	0.25	ND	NR	ND	NR	ND	0.3	NR
Carbon tetrachloride	0.2	ND		ND		ND	ND	
Tribromochloromethane	0.5	ND	ND	ND	ND	ND	ND	ND
Haloacetic acids								
Monochloroacetic acid <sup>d</sup>	2		ND	2.8	2.8	3.0	2.1	
Monobromoacetic acid <sup>d</sup>	1		ND	1.0	1.2	1.3	ND	
Dichloroacetic acid <sup>d</sup>	1		ND	26	26	29	26	
Bromochloroacetic acid <sup>d</sup>	1		ND	15	16	19	14	
Dibromoacetic acid <sup>d</sup>	1		ND	4.8	4.9	6.7	5.9	
Trichloroacetic acid <sup>d</sup>	1		ND	8.0	9.8	11	9.0	
Bromodichloroacetic acid	1		ND	4.9	5.9	6.9	5.6	
Dibromochloroacetic acid	1		ND	1.1	1.3	1.8	1.3	
Tribromoacetic acid	2		ND	ND	ND	ND	ND	
HAA5 <sup>f</sup>			ND	43	45	51	43	
HAA9 <sup>g</sup>			ND	64	68	79	64	
DXAA <sup>h</sup>			ND	46	47	55	46	
TXAA <sup>i</sup>			ND	14	17	20	16	
Haloacetonitriles								
Chloroacetonitrile	0.1	ND	ND	ND	0.1	0.1	0.1	ND
Bromoacetonitrile	0.1	ND	ND	ND	0.2	ND	ND	ND
Dichloroacetonitrile <sup>d</sup>	0.1	ND	ND	1	2	3	2	3
Bromochloroacetonitrile <sup>d</sup>	0.1	ND	ND	0.6	0.9	1	1	1
Dibromoacetonitrile <sup>d</sup>	0.1	ND	ND	0.2	0.4	0.6	0.9	1
Trichloroacetonitrile <sup>d</sup>	0.1	ND	ND	ND	ND	ND	ND	ND
Bromodichloroacetonitrile	0.5	ND		ND		ND		
Dibromochloroacetonitrile	0.5	ND		ND		ND		
Tribromoacetonitrile	0.5	ND		ND		ND		
Haloacetaldehydes								
Dichloroacetaldehyde	0.22	1	0.7	3	5	4	6	6
Bromochloroacetaldehyde	0.5	ND	ND	1	2	2	1	1
Chloral hydrate <sup>d</sup>	0.1	0.5	ND	2	2	2	2	2
Tribromoacetaldehyde	0.1	0.7	0.1	0.7	0.9	0.3	0.1	ND

Table 14 (continued)

09/10/2001	MRL <sup>a</sup>	Plant 12 <sup>k</sup>						
Compound	µg/L	Raw	Pre-Treat	Filt Inf	Filt Eff	Plant Eff	DS/Ave	DS/Max
Haloketones								
Chloropropanone	0.1	ND	ND	0.1	0.1	0.1	0.2	0.3
1,1-Dichloropropanone <sup>d</sup>	0.10	ND	0.1	0.8	1	1	0.8	0.9
1,3-Dichloropropanone	0.1	ND	ND	0.2	ND	ND	ND	ND
1,1-Dibromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloropropanone <sup>d</sup>	0.1	ND	ND	0.1	0.3	0.4	ND	ND
1,1,3-Trichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1,1-Tribromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1,3-Tribromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrachloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1,1,3-Tetrachloropropanone	0.10	ND	0.2	0.5	0.5	0.5	0.4	0.3
1,1,3,3-Tetrabromopropanone	2	ND	ND	ND	ND	ND	ND	ND
Halonitromethanes								
Bromonitromethane	0.1	ND	ND	ND	0.4	ND	ND	ND
Dichloronitromethane	0.1	ND	ND	ND	ND	ND	ND	ND
Bromochloronitromethane	0.1	ND	ND	ND	ND	0.2	ND	ND
Dibromonitromethane	0.10	ND	ND	ND	ND	ND	ND	ND
Chloropicrin <sup>d</sup>	0.1	ND	ND	0.4	0.6	0.9	1	2
Bromodichloronitromethane	0.5	ND		1		2		
Dibromochloronitromethane	0.5	ND		2		2		
Bromopicrin	0.5	ND		2		ND		
Miscellaneous Compounds								
Methyl ethyl ketone	0.5	ND		0.6		ND	0.6	
Methyl <i>tertiary</i> butyl ether	0.2	ND		ND		ND	ND	
Benzyl chloride	0.25	ND	NR	ND	NR	ND	ND	NR
1,1,2,2-Tetrabromo-2-chloroethane	0.5	ND	NR	ND	NR	ND	ND	NR

**Table 15. Additional target DBP results (µg/L) at plant 11 (9/10/01)**

9/10/01	Plant 11 <sup>a</sup>						
Compound	Raw	FI	CWI	CWE	PE	DS	SDS
Monochloroacetaldehyde	0	0	0.2	0	0	0	0
Dichloroacetaldehyde	0	0	1.4	1.2	3.2	2.8	3.5
Bromochloroacetaldehyde	0	0	1.0	1.5	2.8	2.6	1.8
3,3-Dichloropropenoic acid	0	0	0.8	0.9	0.7	0.6	0.6
Bromochloromethylacetate	0	0	0	0	0	0	0
2,2-Dichloroacetamide	0	0	0	2.5	2.8	2.7	2.4
TOX (µg/L as Cl <sup>-</sup> )	33.5	48.1	299	129	126	118	121
Cyanoformaldehyde	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
5-Keto-1-hexanal	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
6-Hydroxy-2-hexanone	<0.1	0.8	<0.1	<0.1	<0.1	<0.1	<0.1
Dimethylglyoxal	<0.1	<0.1	1.1	1.5	1.2	0.8	1.5
<i>trans</i> -2-Hexenal	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

<sup>a</sup>Plant 11 sampled at (1) raw water, (2) filter influent (FI), (3) clearwell influent (CWI), (4) clearwell effluent (CWE), (5) finished water at plant effluent (PE), (6) distribution system (DS) at average detention time, and (6) SDS at maximum detection time.

**Table 16. Additional target DBP results (µg/L) at plant 12 (9/10/01)**

9/10/01	Plant 12 <sup>b</sup>						
Compound	Raw	PT	FI	FE	PE	DS	SDS
Monochloroacetaldehyde	0	0.3			1.2		1.8
Dichloroacetaldehyde	0	0.4	4.2	6.2	5.8	6.5	6.8
Bromochloroacetaldehyde	0	2.1	2.4	3.1	3.0	2.5	2.1
3,3-Dichloropropenoic acid	0	0	0.5	0	0	0	0
Bromochloromethylacetate	0	0	0	0	0	0	0
2,2-Dichloroacetamide	0	0	4.5	4.4	5.6	5.1	5.5
TOX (µg/L as Cl <sup>-</sup> )	6.6	35.0	196	223	260	245	165
Cyanoformaldehyde	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
5-Keto-1-hexanal	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
6-Hydroxy-2-hexanone	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dimethylglyoxal	<0.1	<0.1	2.4	3.1	2.5	2.0	2.9
<i>Trans</i> -2-Hexenal	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

<sup>b</sup>Plant 12 sampled at (1) raw water, (2) pre-treated water (PT), (3) filter influent (FI), (4) filter effluent (FE), (5) finished water at plant effluent (PE), (6) distribution system (DS) at average detention time, and (7) SDS at maximum detection time.

**Table 17. Halogenated furanone results (µg/L) at plant 11 (9/10/01)**

Compound	FI	FE	CWE	PE	DS/ave	SDS/max
BMX-1	<0.02	0.05	0.12	0.17	0.14	0.21
BEMX-1	0.02	<0.02	<0.02 (0.01)	<0.02	<0.02 (0.01)	<0.02
BMX-2	<0.02	<0.02 (0.011)	<0.02 (0.011)	<0.02 (0.016)	<0.02 (0.015)	<0.02 (0.013)
BEMX-2	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
BMX-3	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
BEMX-3	<0.02	0.37	0.31	0.20	<0.02	0.49
MX	<0.02	<0.02	0.02	0.02	0.85	NA
EMX	<0.02	<0.02	<0.02	<0.02	<0.02	NA
ZMX	<0.02	<0.02	0.09	<0.02	<0.02	NA
Mucochloric acid (ring)	<0.02	<0.02	<0.02	<0.02	<0.02	NA
Mucochloric acid (open)	<0.02	<0.02	<0.02	<0.02	<0.02	NA

**Table 18. Halogenated furanone results (µg/L) at plant 12 (9/10/01)**

Compound	Raw	PT	FI	FE	PE	DS/ave	SDS/max
BMX-1	<0.02	<0.02	<0.02	<0.02	0.09	0.08	0.03
BEMX-1	0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
BMX-2	<0.02	<0.02	<0.02	<0.02	0.03	0.02	<0.02 (0.017)
BEMX-2	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
BMX-3	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
BEMX-3	<0.02	<0.02	<0.02	<0.02	<0.02	0.04	<0.02
MX	<0.02	<0.02	<0.02	0.08	<0.02 (0.014)	NA	NA
EMX	<0.02	<0.02	<0.02	<0.02	<0.02	NA	NA
ZMX	<0.02	<0.02	<0.02	<0.02	<0.02	NA	NA
Mucochloric acid (ring)	<0.02	<0.02	<0.02	<0.02	<0.02	NA	NA
Mucochloric acid (open)	<0.02	<0.02	<0.02	<0.02	<0.02	NA	NA

**Table 19. DBP results at plant 11 (11/5/01)**

11/05/2001	MRL <sup>a</sup>	Plant 11 <sup>m</sup>							
Compound	µg/L	Raw	Filt Inf	Clearwell	Plant Eff	DS/Ave	DS/Max	SDS/Ave	SDS/Max
Halomethanes									
Chloromethane	0.2	ND <sup>c</sup>		ND	ND	ND		ND	
Bromomethane	0.2	ND		ND	ND	ND		ND	
Bromochloromethane	0.5	ND		ND	ND	ND		ND	
Dibromomethane	0.5	ND		ND	ND	ND		ND	
Chloroform <sup>d</sup>	0.5	ND	ND	ND	5	7	8	8	9
Bromodichloromethane <sup>d</sup>	0.1	ND	0.1	0.4	14	17	17	18	20
Dibromochloromethane <sup>d</sup>	0.1	ND	ND	0.3	15	16	18	18	19
Bromoform <sup>d</sup>	0.11	ND	ND	ND	3	3	4	3	3
THM4 <sup>e</sup>		ND	0.1	0.7	37	43	47	47	51
Dichloriodomethane	0.5	ND	ND	ND	1	2	NR <sup>l</sup>	2	NR
Bromochloriodomethane	0.25	ND		ND	0.4	0.3		0.4	
Dibromiodomethane	0.52	ND	ND	ND	ND	ND	ND	ND	ND
Chlorodiiodomethane	0.5	ND	NR	ND	ND	ND	NR	ND	NR
Bromodiiodomethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND
Iodoform	2	ND	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.2	ND		ND	ND	ND		ND	
Tribromochloromethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND
Haloacetic acids									
Monochloroacetic acid <sup>d</sup>	2		ND	ND	ND	ND		ND	
Monobromoacetic acid <sup>d</sup>	1		ND	ND	1.1	1.1		1.1	
Dichloroacetic acid <sup>d</sup>	1		ND	ND	8.8	11		11	
Bromochloroacetic acid <sup>d</sup>	1		ND	ND	10	11		11	
Dibromoacetic acid <sup>d</sup>	1		ND	ND	7.9	8.0		8.0	
Trichloroacetic acid <sup>d</sup>	1		ND	ND	4.7	5.3		4.5	
Bromodichloroacetic acid	1		ND	ND	9.6	11		10	
Dibromochloroacetic acid	1		ND	ND	6.2	6.9		5.9	
Tribromoacetic acid	2		ND	ND	ND	ND		ND	
HAA5 <sup>f</sup>			ND	ND	23	25		25	
HAA9 <sup>g</sup>			ND	ND	48	54		52	
DXAA <sup>h</sup>			ND	ND	27	30		30	
TXAA <sup>i</sup>			ND	ND	21	23		20	
Haloacetonitriles									
Chloroacetonitrile	0.1	ND	ND	ND	ND	0.3	ND	0.4	ND
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile <sup>d</sup>	0.10	ND	ND	ND	1	1	2	2	2
Bromochloroacetonitrile <sup>d</sup>	0.1	ND	ND	ND	NR	NR	2	2	2
Dibromoacetonitrile <sup>d</sup>	0.14	ND	ND	ND	2	2	1	2	2
Trichloroacetonitrile <sup>d</sup>	0.1	ND	ND	ND	ND	ND	ND	ND	ND
Bromodichloroacetonitrile	0.5	ND		ND	ND				ND
Dibromochloroacetonitrile	0.5	ND		ND	0.6				0.5
Tribromoacetonitrile	0.90	ND		ND	ND				ND
Haloacetaldehydes									
Dichloroacetaldehyde	1.1	ND	ND	ND	1	2	3	3	3
Bromochloroacetaldehyde	0.5	ND	ND	ND	1	1	1	1	1
Chloral hydrate <sup>d</sup>	0.1	ND	ND	0.1	1	1	1	2	2
Tribromoacetaldehyde	0.5	ND	ND	ND	<0.5 <sup>n</sup>	ND	ND	ND	ND

Table 19 (continued)

11/05/2001	MRL <sup>a</sup>	Plant 11 <sup>m</sup>							
Compound	µg/L	Raw	Filt Inf	Clearwell	Plant Eff	DS/Ave	DS/Max	SDS/Ave	SDS/Max
Haloketones									
Chloropropanone	0.1	ND	ND	ND	0.2	0.1	0.3	ND	ND
1,1-Dichloropropanone <sup>d</sup>	0.10	ND	0.2	0.1	0.5	0.6	0.7	0.8	0.8
1,3-Dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloropropanone <sup>d</sup>	0.1	ND	ND	ND	0.8	0.7	0.7	0.5	0.4
1,1,3-Trichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	1.0	ND	NR	ND	ND	ND	NR	ND	ND
1,1,1-Tribromopropanone	0.29	ND	ND	ND	ND	ND	ND	ND	NR
1,1,3-Tribromopropanone	0.14	ND	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrachloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1,3-Tetrachloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrabromopropanone	0.5	ND	ND	ND	ND	ND	ND	ND	ND
Halonitromethanes									
Bromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	0.1	ND	ND	ND	0.2	0.3	0.3	0.4	0.4
Bromochloronitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND
Dibromonitromethane	0.10	ND	ND	ND	ND	ND	ND	ND	ND
Chloropicrin <sup>d</sup>	0.1	ND	ND	ND	0.1	0.2	0.5	1	1
Bromodichloronitromethane	0.5	ND		ND	0.7				1
Dibromochloronitromethane	2	ND		ND	ND				ND
Bromopicrin	2	ND		ND	ND				ND
Miscellaneous Compounds									
Methyl ethyl ketone	0.5	2		ND	0.8	0.7		0.9	
Methyl <i>tertiary</i> butyl ether	0.2	ND		ND	ND	ND		ND	
Benzyl chloride	0.5	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrabromo-2-chloroethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND

<sup>m</sup> Plant 11 sampled at (1) raw water, (2) filter influent, (3) clearwell influent, (4) plant effluent, DS at (5) average and (6) maximum detention times, and

SDS testing of plant effluent at (7) average and (8) maximum detention times

<sup>n</sup> <0.5: Concentration less than MRL (i.e., 0.5 µg/L)

**Table 20. DBP results at plant 12 (11/15/01)**

11/15/2001	MRL <sup>a</sup>	Plant 12 <sup>k</sup>								
Compound	µg/L	Raw	Pre-Treat	Filt Inf	Filt Eff	Plant Eff	DS/Ave	DS/Max	SDS/Ave	SDS/Max
Halomethanes										
Chloromethane	0.2	ND <sup>c</sup>		ND		ND	ND		ND	
Bromomethane	0.2	ND		ND		ND	ND		ND	
Bromochloromethane	0.5	ND		ND		ND	ND		ND	
Dibromomethane	0.5	ND		ND		ND	ND		ND	
Chloroform <sup>d</sup>	0.1	ND	0.3	7	5	5	11	13	11	11
Bromodichloromethane <sup>d</sup>	0.1	ND	0.3	11	8	10	21	25	20	19
Dibromochloromethane <sup>d</sup>	0.1	ND	ND	6	5	6	15	18	14	14
Bromoform <sup>d</sup>	0.11	ND	ND	2	1	2	9	9	7	8
THM4 <sup>e</sup>		ND	0.6	26	19	23	56	65	52	52
Dichloroiodomethane	0.5	ND	NR <sup>j</sup>	11	NR	11	15	NR	14	NR
Bromochloroiodomethane	0.25	ND		3	2	3	5	4	4	3
Dibromoiodomethane	0.52	ND	ND	1	NR	2	3	3	3	NR
Chlorodiiodomethane	0.5	ND	NR	0.6	NR	2	1	NR	1	NR
Bromodiiodomethane	0.5	ND	ND	ND	ND	0.7	0.7	0.7	ND	ND
Iodoform	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.2	ND		ND		ND	ND		ND	
Tribromochloromethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
Haloacetic acids										
Monochloroacetic acid <sup>d</sup>	2		ND	3.7	3.3	5.5	2.1		2.8	
Monobromoacetic acid <sup>d</sup>	1		ND	ND	ND	ND	1.0		2.7	
Dichloroacetic acid <sup>d</sup>	1		1.1	19	18	22	17		27	
Bromochloroacetic acid <sup>d</sup>	1		ND	21	21	18	18		21	
Dibromoacetic acid <sup>d</sup>	1		ND	8.6	8.6	11	8.2		15	
Trichloroacetic acid <sup>d</sup>	1		ND	4.5	4.2	5.7	7.2		7.1	
Bromodichloroacetic acid	1		ND	3.8	3.9	5.7	5.4		6.7	
Dibromochloroacetic acid	1		ND	1.8	1.7	2.8	2.2		2.8	
Tribromoacetic acid	2		ND	ND	ND	ND	ND		ND	
HAA5 <sup>f</sup>			1.1	36	34	44	36		55	
HAA9 <sup>g</sup>			1.1	62	61	71	61		85	
DXAA <sup>h</sup>			1.1	49	48	51	43		63	
TXAA <sup>i</sup>			ND	10	10	14	15		17	
Haloacetonitriles										
Chloroacetonitrile	0.1	ND	ND	ND	ND	0.4	ND	ND	ND	ND
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile <sup>d</sup>	0.10	ND	ND	1	0.7	2	2	2	2	2
Bromochloroacetonitrile <sup>d</sup>	0.1	ND	ND	0.7	0.4	1	3	2	3	2
Dibromoacetonitrile <sup>d</sup>	0.14	ND	ND	0.5	0.2	0.9	2	0.9	2	1
Trichloroacetonitrile <sup>d</sup>	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromodichloroacetonitrile	0.5	ND		ND		ND				ND
Dibromochloroacetonitrile	0.5	ND		ND		ND				ND
Tribromoacetonitrile	0.90	ND		ND		ND				ND
Haloacetaldehydes										
Dichloroacetaldehyde	0.22	ND	ND	3	2	3	4	4	5	5
Bromochloroacetaldehyde	0.5	ND	ND	1	0.5	2	4	4	3	4
Chloral hydrate <sup>d</sup>	0.1	ND	0.2	1	1	1	2	2	1	2
Tribromoacetaldehyde	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND



Table 20 (continued)

11/15/2001	MRL <sup>a</sup>	Plant 12 <sup>k</sup>								
Compound	µg/L	Raw	Pre-Treat	Filt Inf	Filt Eff	Plant Eff	DS/Ave	DS/Max	SDS/Ave	SDS/Max
Haloketones										
Chloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	0.6	ND
1,1-Dichloropropanone <sup>d</sup>	0.10	ND	0.2	0.7	0.8	0.8	0.8	0.8	0.9	0.7
1,3-Dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	0.10	ND	ND	ND	ND	ND	0.1	0.1	ND	ND
1,1,1-Trichloropropanone <sup>d</sup>	0.1	ND	ND	0.2	ND	0.3	0.4	0.3	0.1	0.1
1,1,3-Trichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Tribromopropanone	2.5	ND	NR	ND	NR	ND	ND	NR	ND	NR
1,1,3-Tribromopropanone	0.14	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrachloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1,3-Tetrachloropropanone	0.10	ND	ND	0.1	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrabromopropanone	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
Halonitromethanes										
Bromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	0.1	ND	ND	0.3	0.3	0.4	0.6	0.9	ND	0.4
Bromochloronitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloropicrin <sup>d</sup>	0.1	ND	ND	0.3	0.2	0.7	1	0.9	2	1
Bromodichloronitromethane	0.5	ND		1		1				ND
Dibromochloronitromethane	0.5	ND		2		1				1
Bromopicrin	0.5	ND		2		2				0.7
Miscellaneous Compounds										
Methyl ethyl ketone	0.5	1		ND		0.7	0.8		1	
Methyl <i>tertiary</i> butyl ether	0.2	ND		ND		ND	ND		0.3	
Benzyl chloride	0.5	ND	ND	ND	ND	ND	ND	ND	ND	NR
1,1,2,2-Tetrabromo-2-chloroethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND

**Table 21. Occurrence of other DBPs<sup>a</sup> at plant 12: plant effluent (11/15/01)**

<u>Halomethanes</u> <i>Bromodichloromethane<sup>b</sup></i> <i>Dibromochloromethane</i> <i>Bromoform</i> <i>Dichloroiodomethane</i> <i>Bromochloroiodomethane</i> <i>Dibromoiodomethane</i> <i>Chlorodiiodomethane</i> <i>Bromodiiodomethane</i>	<u>Haloketones</u> <i>1,1-Dibromo-3,3-dichloropropanone</i> <i>1,3-Dibromo-1,3-dichloropropanone</i> <i>1,1,3-Tribromo-3-chloropropanone</i> <i>1,1,3,3-Tetrabromopropanone</i> <i>Pentachloropropanone</i>
<u>Haloacids</u> <i>Iodoacetic acid</i> <i>Dichloroacetic acid</i> <i>Bromochloroacetic acid</i> <i>Dibromoacetic acid</i> <i>Iodobromoacetic acid</i> <i>Tribromoacetic acid</i> <i>3,3-Dichloropropenoic acid</i> <i>3,3-Dibromopropenoic acid</i> <i>Iodobromopropenoic acid<sup>c</sup> (2 isomers)</i> <i>cis-2-Bromo-butenedioic acid</i> <i>2-Iodo-3-methylbutenedioic acid</i>	<u>Miscellaneous Halogenated DBPs</u> <i>Dibromoaniline</i> <i>Dibromodichloroaniline</i> <i>Tribromochloroaniline</i>
<u>Haloacetonitriles</u> <i>Bromochloroacetonitrile</i> <i>Dibromoacetonitrile</i>	<u>Non-halogenated DBPs</u> <i>Acetone</i> <i>Glyoxal</i> <i>Hexanoic acid</i> <i>Heptanoic acid</i> <i>Octanoic acid</i> <i>Nonanoic acid</i> <i>Decanoic acid</i> <i>Dodecanoic acid</i> <i>Tetradecanoic acid</i> <i>Hexanedioic acid</i> <i>Decanedioic acid</i> <i>Undecanedioic acid</i>
<u>Haloaldehydes</u> <i>2-Bromo-2-methylpropanal</i>	

<sup>a</sup>DBPs detected by broadscreen gas chromatography/mass spectrometry (GC/MS) technique.

<sup>b</sup>Compounds listed in italics were confirmed through the analysis of authentic standards; haloacids and non-halogenated carboxylic acids identified as their methyl esters.

<sup>c</sup>Exact isomer not known

**Table 22. DBP results at plant 11 (2/11/02)**

02/11/2002	MRL <sup>a</sup>	Plant 11 <sup>m</sup>							
Compound	µg/L	Raw	Filt Inf	Clearwell	Plant Eff	DS/Ave	DS/Max	SDS/Ave	SDS/Max
Halomethanes									
Chloromethane	0.2	ND <sup>c</sup>		ND	ND	ND		ND	
Bromomethane	0.2	ND		ND	ND	ND		ND	
Bromochloromethane	0.5	ND		ND	ND	ND		ND	
Dibromomethane	0.5	ND		ND	ND	ND		ND	
Chloroform <sup>d</sup>	0.2	ND	NR <sup>j</sup>	4	5	7	NR	6	NR
Bromodichloromethane <sup>d</sup>	0.5	ND	NR	4	9	10	NR	11	NR
Dibromochloromethane <sup>d</sup>	0.25	ND	NR	5	10	11	NR	12	NR
Bromoform <sup>d</sup>	0.5	ND	NR	2	4	4	NR	4	NR
THM4 <sup>e</sup>		ND	NR	15	28	32	NR	33	NR
Dichloroiodomethane	1.0	ND	NR	<1 <sup>o</sup>	<1	<1	NR	<1	NR
Bromochloroiodomethane	0.5	ND	ND	<0.5 <sup>n</sup>	<0.5	<0.5	ND	0.7	ND
Dibromoiodomethane	0.53	ND	ND	ND	ND	0.6	ND	ND	ND
Chlorodiiodomethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND
Bromodiiodomethane	0.52	ND	ND	ND	ND	ND	ND	ND	ND
Iodoform	2.2	ND	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.2	ND		ND	ND	ND		ND	
Tribromochloromethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND
Haloacetic acids									
Monochloroacetic acid <sup>d</sup>	2		ND	3.0	2.8	2.8		3.2	
Monobromoacetic acid <sup>d</sup>	1		ND	1.0	1.4	1.5		1.6	
Dichloroacetic acid <sup>d</sup>	1		4.8	6.6	6.7	9.2		8.0	
Bromochloroacetic acid <sup>d</sup>	1		ND	5.0	6.3	6.3		6.2	
Dibromoacetic acid <sup>d</sup>	1		ND	5.7	6.1	5.5		5.3	
Trichloroacetic acid <sup>d</sup>	1		2.0	3.4	4.4	4.7		4.0	
Bromodichloroacetic acid	1		ND	6.6	9.0	8.8		8.6	
Dibromochloroacetic acid	1		ND	6.2	9.1	8.7		8.5	
Tribromoacetic acid	2		ND	ND	ND	4.6		ND	
HAA5 <sup>f</sup>			6.8	20	21	24		22	
HAA9 <sup>g</sup>			6.8	38	46	52		45	
DXAA <sup>h</sup>			4.8	17	19	21		20	
TXAA <sup>i</sup>			2.0	16	23	27		21	
Haloacetonitriles									
Chloroacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile <sup>d</sup>	2.5	ND	NR	<1	<1	<1	NR	<1	NR
Bromochloroacetonitrile <sup>d</sup>	0.5	ND	ND	0.5	2	2	NR	2	NR
Dibromoacetonitrile <sup>d</sup>	1.0	ND	ND	<1	2	2	NR	2	NR
Trichloroacetonitrile <sup>d</sup>	0.1	ND	ND	ND	ND	ND	ND	ND	ND
Bromodichloroacetonitrile	0.5	ND		ND	ND				ND
Dibromochloroacetonitrile	0.5	ND		ND	ND				ND
Tribromoacetonitrile	0.90	ND		ND	ND				ND
Haloacetaldehydes									
Dichloroacetaldehyde	0.98	ND	ND	ND	ND	ND	ND	ND	ND
Bromochloroacetaldehyde	0.5	ND	ND	ND	0.6	0.7	0.7	0.8	0.8
Chloral hydrate <sup>d</sup>	0.1	0.5	0.2	0.2	0.3	0.3	0.3	0.5	0.4
Tribromoacetaldehyde	0.1	ND	ND	ND	ND	ND	ND	ND	ND

Table 22 (continued)

02/11/2002	MRL <sup>a</sup>	Plant 11 <sup>m</sup>							
Compound	µg/L	Raw	Filt Inf	Clearwell	Plant Eff	DS/Ave	DS/Max	SDS/Ave	SDS/Max
Haloketones									
Chloropropanone	0.1	ND	0.1	1	1	1	0.5	1	1
1,1-Dichloropropanone <sup>d</sup>	1.0	ND	1	1	<1	<1	<1	<1	<1
1,3-Dichloropropanone	0.1	0.2	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	0.1	ND	ND	0.4	0.3	0.4	0.2	0.2	0.2
1,1,1-Trichloropropanone <sup>d</sup>	0.5	ND	<0.5	0.9	0.8	0.8	0.9	0.7	0.9
1,1,3-Trichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	0.1	ND	ND	0.2	0.4	ND	ND	0.1	ND
1,1,1-Tribromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND
1,1,3-Tribromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrachloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1,3-Tetrachloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrabromopropanone	0.5	ND	ND	ND	ND	ND	ND	ND	ND
Halonitromethanes									
Chloronitromethane	NA	ND		ND	ND	ND		ND	
Bromonitromethane	0.1	ND	ND	ND	ND	0.1	ND	ND	ND
Dichloronitromethane	0.10	ND	ND	ND	ND	ND	ND	ND	ND
Bromochloronitromethane	0.1	ND	ND	0.1	0.1	0.1	0.2	0.2	0.2
Dibromonitromethane	0.10	ND	ND	ND	ND	0.1	ND	0.1	ND
Chloropicrin <sup>d</sup>	0.1	ND	ND	0.3	0.4	0.2	0.4	0.4	0.7
Bromodichloronitromethane	2	ND		ND	ND				ND
Dibromochloronitromethane	2	ND		ND	ND				ND
Bromopicrin	0.5	ND		ND	1				ND
Miscellaneous Compounds									
Methyl ethyl ketone	0.5	ND		ND	ND	ND		ND	
Methyl <i>tertiary</i> butyl ether	0.2	ND		ND	ND	ND		ND	
Benzyl chloride	0.5	ND	NR	ND	ND	ND	NR	ND	NR
1,1,2,2-Tetrabromo-2-chloroethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND

<sup>a</sup><1.0: Concentration less than MRL (e.g., 1.0 µg/L)

**Table 23. DBP results at plant 12 (2/12/02)**

02/12/2002	MRL <sup>a</sup>	Plant 12 <sup>k</sup>								
Compound	µg/L	Raw	Pre-Treat	Filt Inf	Filt Eff	Plant Eff	DS/Ave	DS/Max	SDS/Ave	SDS/Max
Halomethanes										
Chloromethane	0.2		ND <sup>c</sup>	ND		ND	ND		ND	
Bromomethane	0.2		ND	ND		ND	ND		ND	
Bromochloromethane	0.5		ND	ND		ND	ND		ND	
Dibromomethane	0.5		ND	ND		ND	ND		ND	
Chloroform <sup>d</sup>	0.2	ND	0.4	3	NR <sup>i</sup>	3	3	NR	3	NR
Bromodichloromethane <sup>d</sup>	0.5	ND	0.8	12	NR	14	15	NR	12	NR
Dibromochloromethane <sup>d</sup>	0.25	ND	1	19	NR	21	23	NR	19	NR
Bromoform <sup>d</sup>	0.5	ND	0.5	17	NR	19	19	NR	16	NR
THM4 <sup>e</sup>		ND	3	51	NR	57	60	NR	50	NR
Dichloriodomethane	1.0	ND	NR	<1 <sup>o</sup>	NR	<1	<1	NR	<1	NR
Bromochloriodomethane	0.5	ND	ND	2	NR	2	3	NR	2	NR
Dibromiodomethane	0.53	ND	ND	3	NR	4	4	NR	3	NR
Chlorodiodomethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromodiodomethane	0.52	ND	ND	ND	ND	<0.5 <sup>n</sup>	<0.5	<0.5	ND	ND
Iodoform	2.2	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.2		ND	ND		ND	ND		ND	
Tribromochloromethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
Haloacetic acids										
Monochloroacetic acid <sup>d</sup>	2		3.9	3.2	3.2	3.0	2.1		2.6	
Monobromoacetic acid <sup>d</sup>	1		1.3	2.2	2.2	2.1	2.5		2.0	
Dichloroacetic acid <sup>d</sup>	1		7.8	11	11	10	18		9.6	
Bromochloroacetic acid <sup>d</sup>	1		6.9	14	13	14	22		14	
Dibromoacetic acid <sup>d</sup>	1		6.6	16	14	18	22		16	
Trichloroacetic acid <sup>d</sup>	1		ND	2.4	2.2	3.1	3.8		2.7	
Bromodichloroacetic acid	1		4.7	6.5	8.0	9.0	9.7		9.1	
Dibromochloroacetic acid	1		1.2	6.3	5.9	8.1	8.8		7.5	
Tribromoacetic acid	2		ND	ND	ND	ND	ND		ND	
HAA5 <sup>f</sup>			20	35	33	36	48		33	
HAA9 <sup>g</sup>			32	62	60	67	89		64	
DXAA <sup>h</sup>			21	41	38	42	62		40	
TXAA <sup>i</sup>			5.9	15	16	20	22		19	
Haloacetonitriles										
Chloroacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile <sup>d</sup>	2.5	ND	ND	<1	NR	<1	<1	NR	<1	<1
Bromochloroacetonitrile <sup>d</sup>	0.5	ND	NR	1	NR	2	2	NR	2	NR
Dibromoacetonitrile <sup>d</sup>	1.0	ND	NR	1	NR	2	2	NR	2	NR
Trichloroacetonitrile <sup>d</sup>	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromodichloroacetonitrile	0.5		ND	ND		ND				ND
Dibromochloroacetonitrile	0.5		ND	ND		ND				ND
Tribromoacetonitrile	0.90		ND	ND		ND				ND
Haloacetaldehydes										
Dichloroacetaldehyde	0.98	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromochloroacetaldehyde	0.5	ND	ND	2	2	2	2	2	2	2
Chloral hydrate <sup>d</sup>	0.1	0.6	ND	0.7	0.5	0.7	0.9	1	0.8	0.7
Tribromoacetaldehyde	0.1	ND	ND	2	1	2	1	0.6	2	2

Table 23 (continued)

02/12/2002	MRL <sup>a</sup>	Plant 12 <sup>k</sup>								
Compound	µg/L	Raw	Pre-Treat	Filt Inf	Filt Eff	Plant Eff	DS/Ave	DS/Max	SDS/Ave	SDS/Max
Haloketones										
Chloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloropropanone <sup>d</sup>	1.0	ND	<1	<1	<1	<1	<1	<1	<1	<1
1,3-Dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	0.1	ND	0.3	0.4	0.3	0.4	0.2	0.2	0.4	0.4
1,1,1-Trichloropropanone <sup>d</sup>	0.5	ND	<0.5	0.6	<0.5	0.6	<0.5	<0.5	0.6	0.6
1,1,3-Trichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	0.1	ND	ND	0.5	0.1	0.5	0.1	ND	0.6	0.2
1,1,1-Tribromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,3-Tribromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrachloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1,3-Tetrachloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrabromopropanone	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
Halonitromethanes										
Chloronitromethane	NA		ND	ND		ND	ND		ND	
Bromonitromethane	0.1	ND	ND	ND	0.1	0.2	ND	ND	ND	ND
Dichloronitromethane	0.10	ND	ND	0.3	0.2	0.3	0.3	0.3	0.2	0.2
Bromochloronitromethane	0.1	ND	0.2	0.7	0.7	0.7	0.9	0.9	0.8	0.8
Dibromonitromethane	0.10	ND	ND	0.5	0.4	0.5	0.4	0.4	0.5	0.6
Chloropicrin <sup>d</sup>	0.1	ND	ND	0.4	0.4	0.4	0.7	1	0.4	0.4
Bromodichloronitromethane	2		ND	ND		ND				ND
Dibromochloronitromethane	2		ND	3		3				3
Bromopicrin	0.5		ND	4		5				5
Miscellaneous Compounds										
Methyl ethyl ketone	0.5		ND	ND		ND	ND		ND	
Methyl tertiary butyl ether	0.2		ND	ND		ND	ND		ND	
Benzyl chloride	1.0	ND	NR	ND	NR	ND	ND	NR	ND	NR
1,1,2,2-Tetrabromo-2-chloroethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND

**Table 24. Additional target DBP results (µg/L) at plant 11 (2/11/02)**

2/11/02	Plant 11 <sup>c</sup>		
Compound	FI	PE	DS
Monochloroacetaldehyde	0	0.2	1.6
Dichloroacetaldehyde	0	1.8	6.7
Bromochloroacetaldehyde	0	2.0	3.1
3,3-Dichloropropenoic acid	0	0	0
Bromochloromethylacetate	0	0	0
Monochloroacetamide	0	0.4	0.6
Monobromoacetamide	0	0.8	1.0
2,2-Dichloroacetamide	0	1.4	1.0
Dibromoacetamide	0	1.8	1.5
Trichloroacetamide	0	1.1	0.8
TOX (µg/L as Cl <sup>-</sup> )	57.0	151	139
TOBr (µg/L as Br <sup>-</sup> )	59.3	79.0	83.0
TOCl (µg/L as Cl <sup>-</sup> )	14.6	105	102
Cyanoformaldehyde	<0.1	<0.1	<0.1
5-Keto-1-hexanal	<0.1	<0.1	<0.1
6-Hydroxy-2-hexanone	<0.1	<0.1	<0.1
Dimethylglyoxal	<0.1	1.4	1.1
<i>trans</i> -2-Hexenal	<0.1	<0.1	<0.1

<sup>c</sup>Plant 11 sampled at (1) FI, (2) PE, and (3) DS at maximum detention time.

**Table 25. Additional target DBP results (µg/L) at plant 12 (2/12/02)**

2/12/02	Plant 12 <sup>d</sup>			
Compound	FI	FE	PE	DS
Monochloroacetaldehyde	0.5	0.5	0.1	0.4
Dichloroacetaldehyde	2.1	2.1	1.3	2.4
Bromochloroacetaldehyde	2.1	2.1	4.0	4.0
3,3-Dichloropropenoic acid	0		0	0
Bromochloromethylacetate	0		0	0
Monochloroacetamide	1.0		0.5	0.8
Monobromoacetamide	1.5		1.1	1.0
2,2-Dichloroacetamide	2.4		2.0	1.5
Dibromoacetamide	2.5		2.8	2.2
Trichloroacetamide	0.9		1.0	1.1
TOX (µg/L as Cl <sup>-</sup> )	236		211	212
TOBr (µg/L as Br <sup>-</sup> )	250		229	212
TOCl (µg/L as Cl <sup>-</sup> )	108		145	139
Cyanoformaldehyde	<0.1		<0.1	<0.1
5-Keto-1-hexanal	<0.1		<0.1	<0.1
6-Hydroxy-2-hexanone	<0.1		<0.1	<0.1
Dimethylglyoxal	3.2		1.5	1.9
<i>trans</i> -2-Hexenal	<0.1		<0.1	<0.1

<sup>d</sup>Plant 12 sampled at (1) FI, (2) FE, (3) PE, and (4) DS at maximum detention time.

**Table 26. Halogenated furanone results (µg/L) at plant 11 (2/11/02)**

Compound	FI	PE	DS/max
BMX-1	<0.02	0.08	<0.02
BEMX-1	<0.02	<0.02	<0.02
BMX-2	<0.02	<0.02	<0.02
BEMX-2	<0.02	<0.02	<0.02
BMX-3	<0.02	<0.02	<0.02
BEMX-3	<0.02	<0.02	<0.02
MX	<0.02	<0.02	0.03
EMX	<0.02	<0.02	<0.02
ZMX	<0.02	<0.02	<0.02
Ox-MX	<0.02	<0.02	<0.02
Mucochloric acid ( <i>ring</i> )	0.02	0.04	0.06
Mucochloric acid ( <i>open</i> )	<0.02 (0.01)	0.02	0.02

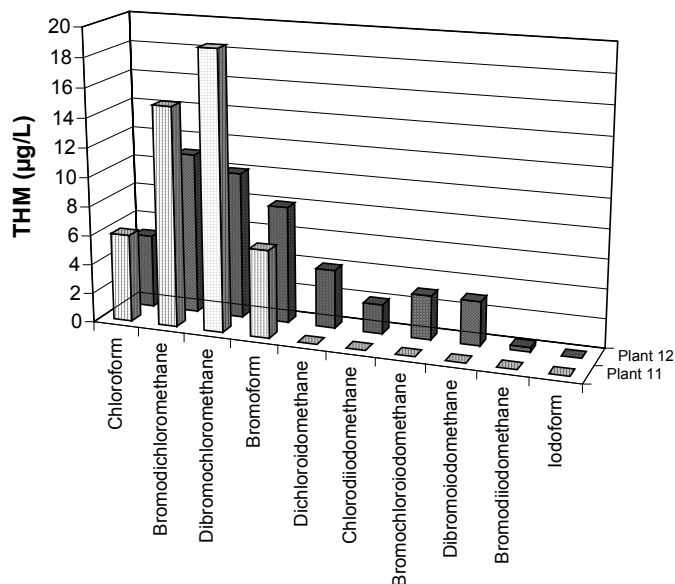
**Table 27. Halogenated furanone results (µg/L) at plant 12 (2/12/02)**

Compound	FI	PE	DS/max
BMX-1	<0.02	0.06	<0.02
BEMX-1	<0.02	<0.02	<0.02
BMX-2	<0.02	<0.02	<0.02
BEMX-2	<0.02	<0.02	<0.02
BMX-3	<0.02	<0.02	<0.02
BEMX-3	<0.02	<0.02	<0.02
MX	<0.02 (0.01)	0.03	<0.02 (0.01)
EMX	<0.02	<0.02	<0.02
ZMX	<0.02	<0.02	<0.02
Ox-MX	<0.02	<0.02	<0.02
Mucochloric acid ( <i>ring</i> )	0.13	0.08	0.06
Mucochloric acid ( <i>open</i> )	<0.02	<0.02	<0.02



**Figure 6. March 26, 2001**

**Effect of Bromide and Iodide and Disinfection Scheme on  
THM Speciation in Plant Effluents at Plant 11 (Chlorine Dioxide/  
Chlorine/Chloramines) and Plant 12 (Chloramines Only)**



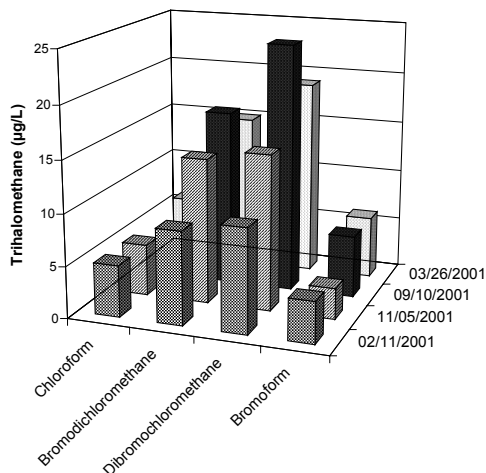
*Halomethanes.* Chlorine dioxide/chlorine/chloramine disinfection at plant 11 resulted in the formation of 28-49 µg/L of the four regulated trihalomethanes (THM4) in the plant effluent in March 2001, September 2001, November 2001, and February 2002. Chloramine disinfection at plant 12 resulted in the formation of 23-57 µg/L of THM4 in the plant effluent in March 2001, September 2001, November 2001, and February 2002. Even with chloramines only, a fair amount of THMs was formed at plant 12. Because of the relatively high amount of TOC and/or bromide in these EPA Region 6 waters, THM formation potentials were probably high; thus, alternative disinfectants were used to minimize THM formation.

In March 2001, because of the high level of bromide in these waters, the major THMs formed were mixed bromochloro species (Figure 6). In addition, sub-µg/L levels of two iodinated THMs were detected in selected samples at plant 11, whereas µg/L levels of five iodinated THMs were detected at plant 12 (Figure 6). In addition to bromide in the source water, there was iodide as well. In other research, the formation of iodinated THMs was favored by chloramination, especially if the ammonia was added first, whereas the addition of chlorine first was found to favor the formation of the bromochloro species (Bichsel and von Gunten, 2000). Although the source water concentration of iodide was not measured in this study, the level of bromide in both source waters was comparable in March 2001. The difference in the formation of iodinated THMs at these two utilities may have been due to the order of addition of the chlorine and ammonia (chlorine first at plant 11, chlorine and ammonia together at plant 12).

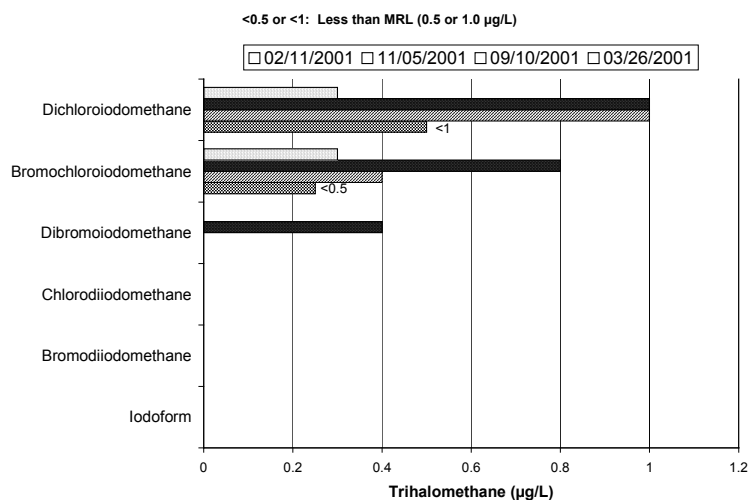
At plant 11, there was no significant seasonal variation in THM speciation (Figure 7). However, the formation of THM4 was highest in September 2001 when the water temperature

was the warmest (25°C) and was the lowest in February 2002 when the water temperature was the coldest (11°C). Likewise, there was a similar seasonal variation in iodinated THM formation (Figure 8), with more formation in September 2001 and less in March 2001 (18°C) and in February 2002.

**Figure 7. Seasonal formation and speciation of THMs at plant 11 effluent**

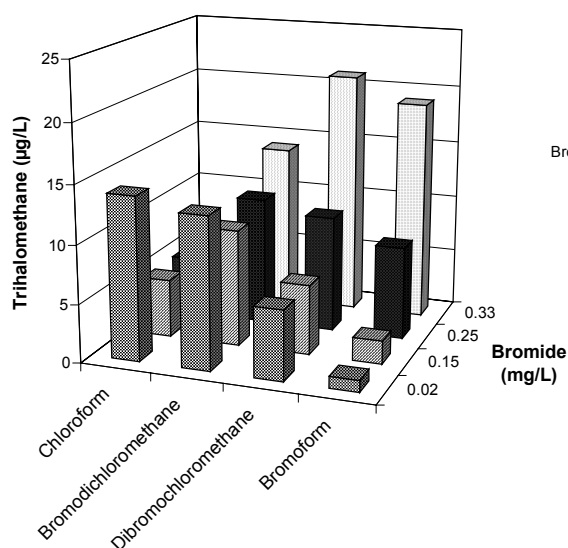


**Figure 8. Seasonal variations in iodinated THM formation at plant 11 clearwell or plant effluent**

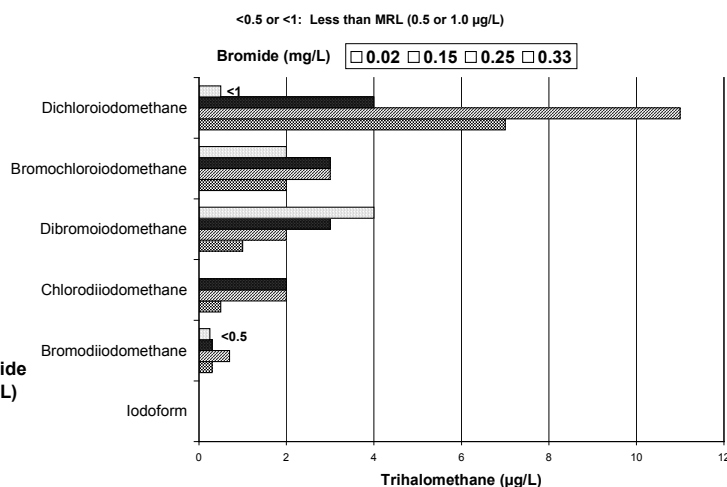


At plant 12, because of the high level of bromide in this water in March 2001 (0.25 mg/L) and February 2002 (0.33 mg/L), the major THMs formed were brominated species (Figure 9). Alternatively, in September 2001 the low level of bromide (0.02 mg/L) resulted in a shift to more highly chlorinated THMs (Figure 9). In addition, µg/L levels of five of the iodinated THMs were detected in these samples (Figure 10). The sixth iodinated THM, iodoform, was detected in only one sample (in the distribution system) in September 2001. The iodinated THMs formed included various combinations of chlorine, bromine, and iodide atoms. Similar to the THM4 speciation (Figure 9), as the level of bromide increased, the formation of dibromoiodomethane increased (from 1 to 4 µg/L), whereas the formation of dichloroiodomethane decreased (from 7-11 down to <1 µg/L) (Figure 10).

**Figure 9. Impact of bromide on THM speciation at plant 12 effluent**



**Figure 10. Seasonal variations in iodinated THM speciation at plant 12 effluent**

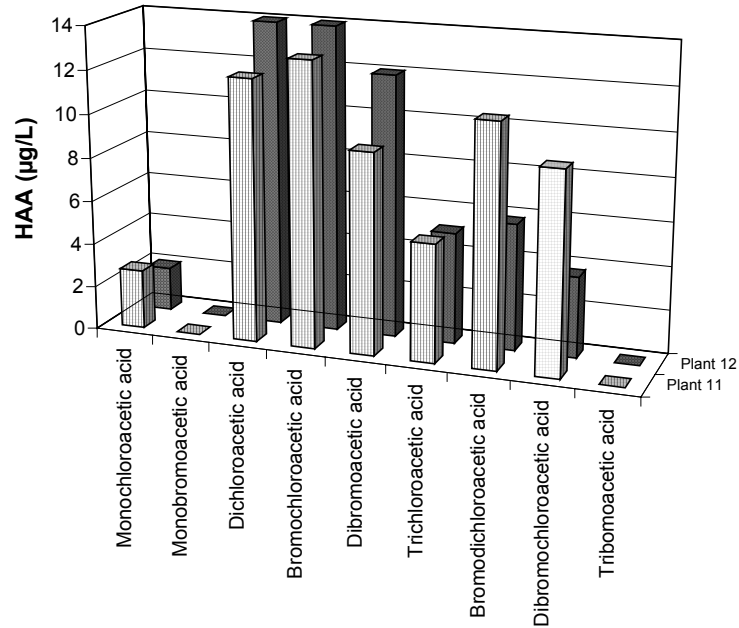


*Haloacids.* Chlorine dioxide/chlorine/chloramine disinfection at plant 11 resulted in the formation of 18-23 µg/L of the five regulated haloacetic acids (HAA5) in the plant effluent in March 2001, September 2001, November 2001, and February 2002. In addition, all nine HAAs (HAA9) were measured, which included all of the brominated HAA species. The levels of HAA9 in the plant effluents in March 2001, September 2001, November 2001, and February 2002 at plant 11 were 42-49 µg/L. In March 2001, September 2001, November 2001, and February 2002, (chlorine dioxide and) chloramine disinfection at plant 12 resulted in the formation of 31-51 and 56-79 µg/L of HAA5 and HAA9, respectively, in the plant effluents. At these two plants, variations in bromide and disinfection practices impacted HAA formation and speciation (see discussion below).

Because of the high level of bromide in these waters in March 2001, a major portion of the HAAs formed in the plant effluent and distribution system were the mixed bromochloro species (i.e., bromochloro-, bromodichloro-, and dibromochloroacetic acid) (Figure 11). At plant 11 in March 2001, the formation of dihalogenated HAAs (DXAAs) was somewhat higher than the formation of the trihalogenated species (TXAAs) (Figure 12). The monohalogenated HAAs (MXAAs) were formed to a very low extent (as is found in other waters [Krasner et al., 1989]). A different pattern was observed at plant 12 in March 2001. At plant 12, the formation of DXAAs was significantly higher than the formation of TXAAs (Figure 12).

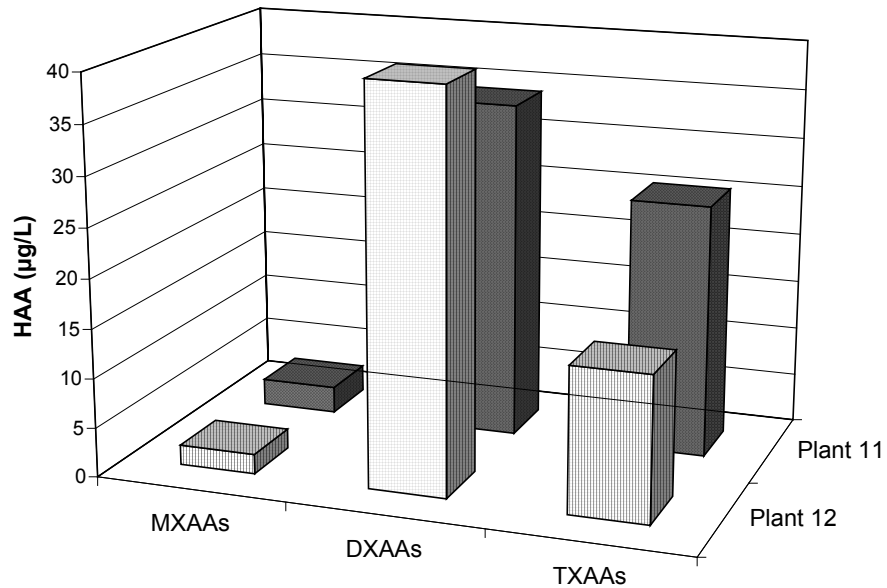
**Figure 11. March 26, 2001**

**Effect of Bromide on HAA Speciation at Plants 11 and 12 in Simulated Distribution System Samples/Average Detention Time**



**Figure 12. March 26, 2001**

**Effect of Disinfection Scheme on HAA Speciation in Plant Effluents at Plant 11 (Chlorine Dioxide/Chlorine/Chloramines) and Plant 12 (Chloramines Only)**

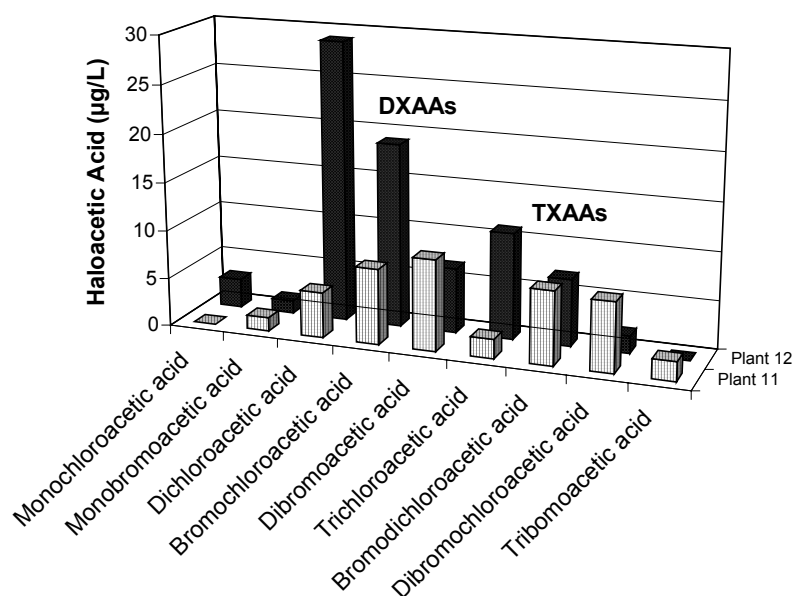


In other research, chlorine dioxide (Zhang et al., 2000) and chloramines (Krasner et al., 1996) have both been shown to produce little or no TXAAs, whereas DXAAs have been formed. The use of chloramines only at plant 12 did minimize TXAA formation much more than DXAA formation, whereas the formation of both types of HAAs at plant 11 was probably due to the presence of free chlorine in the clearwell. Because of the presence of a significant amount of THMs at plant 11, it is likely that most of the THMs and HAAs formed at this plant is due to the free chlorine usage. In other research, waters with relatively low levels of specific UV absorbance (SUVA) have formed more DXAAs than TXAAs (Hwang et al., 2000). The SUVA of the water at plant 11, especially at the point of disinfectant addition (i.e., 2.1 L/mg-m in March 2001), was relatively low. It is likely that a combination of the disinfection scheme and natural organic matter of the water resulted in a higher formation of DXAAs than TXAAs at plant 11.

Because of the higher level of bromide at plant 11 as compared to plant 12 in September 2001, there was a greater shift to the formation of brominated HAAs at plant 11 than at plant 12 (Figure 13). At both plants, there was 19-20 µg/L of TXAAs in the plant effluent (Figure 14), with the major difference for this DBP subclass being the bromine speciation (Figure 13). Alternatively, there was much more formation of DXAAs in the plant effluent at plant 12 than at plant 11 (55 versus 23 µg/L) (Figure 14). The change in bromide levels at plant 12—between March and September 2001—resulted in a shift in HAA speciation between chlorinated and brominated species (Figures 11 and 13). However, the relative formation of DXAAs and TXAAs was comparable in March and September 2001 at plant 12 (Figures 12 and 14), which was due to the use of chloramines only.

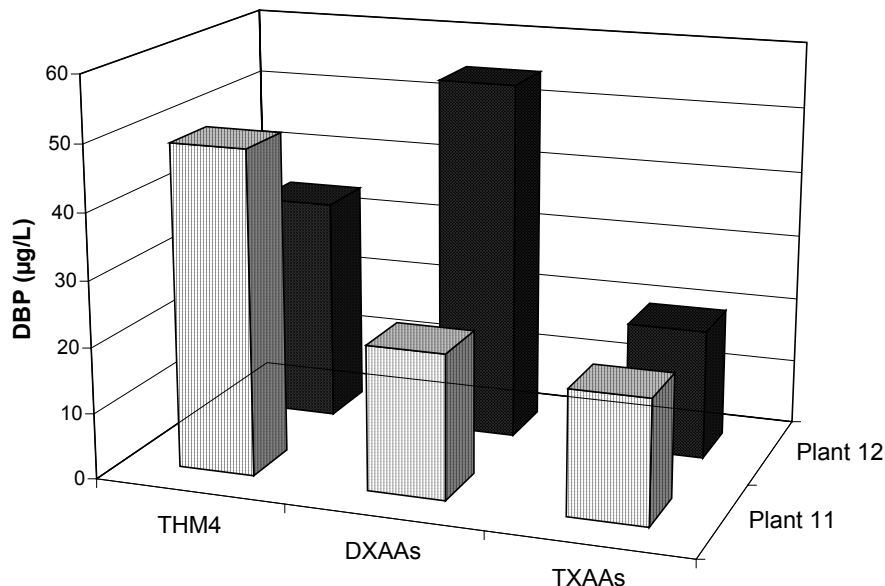
**Figure 13. 9/10/01 (plant 11 Br<sup>-</sup> = 0.21 mg/L, plant 12 Br<sup>-</sup> = 0.02 mg/L)**

**Effect of Bromide and Disinfection Scheme on HAA Formation and Speciation in Plant Effluents at Plant 11 (Chlorine Dioxide/Chlorine/Chloramines) and Plant 12 (Chloramines Only)**



**Figure 14. September 10, 2001**

**Effect of Disinfection Scheme on THM and HAA Formation and Speciation in Plant Effluents at Plant 11 (Chlorine Dioxide/Chlorine/Chloramines) and Plant 12 (Chloramines Only)**



At plant 11 in November 2001, chlorine dioxide was initially dosed before the clarifier. No HAAs and essentially no THMs were detected from pre-disinfection with chlorine dioxide. At plant 11 in February 2002, chlorine dioxide was initially dosed at the clarifier. HAAs (5 and 2 µg/L of dichloro- and trichloroacetic acid, respectively) were detected from pre-disinfection with chlorine dioxide. THM data for the filter influent sample were not reported due to quality control problems. However, the primary THM detected at that sample site was chloroform. At plant 11 in February 2002, after the addition of chlorine, significantly more THMs and HAAs were detected, which included the brominated species. It is possible that there was some DBP formation during the preparation of the chlorine dioxide solution, when the chlorine dioxide gas was dissolved in water.

At plant 12 in February 2002, a significant level of HAA9 (32 µg/L) was produced during pre-treatment with chlorine dioxide disinfection, whereas very little THMs (3 µg/L) were formed. The majority of the HAAs produced were DXAAs (21 µg/L). These results are consistent with that of Zhang and colleagues (2000), in which chlorine dioxide was found to form very little THMs or TXAAs, but did form a significant amount of DXAAs.

In addition to the target HAAs, several new brominated acids were identified by the broadscreen gas chromatography/mass spectrometry (GC/MS) methods (Tables 12 and 21). For example, 2,2-dibromopropanoic acid, dibromochloropropanoic acid, 3,3-dibromopropenoic acid, bromochloro-4-oxo-pentanoic acid, 3,3-dibromo-4-oxopentanoic acid, bromoheptanoic acid, bromochloroheptanoic acid, bromochlorononanoic acid, dibromoheptanoic acid, and cis-2-bromo-3-methylbutenedioic acid were identified (Table 12). Several of these bromo-acids were

also seen in finished waters from plant 1 (EPA Region 9), and also in drinking waters from Israel that had been treated with chlorine or chlorine dioxide-chloramine (Richardson et al., submitted).

At plant 12, in addition to the detection of brominated acids, five iodinated acids were detected (Table 21; mass spectra included in the Appendix). This represents the first time an iodo-acid has been identified as a DBP in drinking water. The identification of iodoacetic acid was confirmed through the analysis of an authentic standard (match of retention time and mass spectrum). Other identifications should be considered tentative until authentic chemical standards can be obtained to confirm them. However, high resolution mass spectrometry confirmed the presence of iodine in their structures, as well as their overall empirical formulas. In the case of iodobromoacetic acid, this assignment is very confident, due to only one isomer being possible. An attempt is currently being made to synthesize chemical standards for the remaining compounds to confirm their identities.

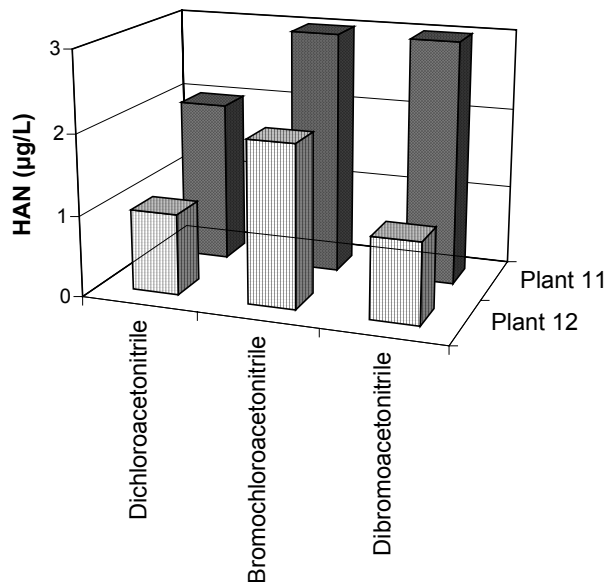
Finally, target analysis carried out by UNC revealed the presence of 3,3-dichloropropenoic acid in finished water from plant 11 in September 2001 (Table 15). It was present at 0.7 µg/L in the finished water and remained stable in the distribution system. 3,3-Dichloropropenoic acid was also formed at plant 12 in September 2001 but was not detected in downstream locations (Table 16).

*Haloacetonitriles.* In other DBP research, haloacetonitriles (HANs) have been found to be produced at approximately one-tenth the level (10 %) of the THMs (Oliver, 1983). A somewhat higher amount (on a relative basis) was detected in the plant 11 samples in March 2001, and a somewhat lower amount was detected in September 2001. A somewhat higher amount (12 and 14 % in March and September 2001, respectively) was detected in the plant 12 samples.

Because of the high level of bromide in these waters in March 2001, brominated HANs predominated (Figure 15). Although plant 12 had somewhat more raw-water bromide than plant 11 in March 2001, the shift in speciation to the more brominated HANs was greater in the plant 11 samples. This may have been due, in part, to differences in the formation of brominated DBPs in the presence of chlorine (i.e., at plant 11) and in the presence of chloramines (i.e., at plant 12). In the presence of chlorine, bromide is oxidized to hypobromous acid, which is a very powerful halogenation agent. In the presence of chloramines, bromide can be converted to bromamines, which will not produce as much brominated DBPs as hypobromous acid.

**Figure 15. March 26, 2001**

**Effect of Bromide and Disinfection Scheme on HAN Speciation in Plants Effluents at Plant 11 (Chlorine Dioxide/Chlorine/Chloramines) and Plant 12 (Chloramines Only)**



Because of the higher level of bromide at plant 11 than plant 12 in September 2001, there was a significantly greater shift to the formation of brominated HANs at plant 11 than at plant 12 that month (Figure 16). In addition to the formation of more of the brominated HANs in the Information Collection Rule (ICR) (e.g., dibromoacetonitrile) at plant 11, the target HAN dibromochloroacetonitrile was detected at plant 11 but not at plant 12 in September and November 2001.

Chloroacetonitrile, another target HAN, was detected at both plants in September 2001 (Figure 16) and November 2001. In addition, bromoacetonitrile was detected in one sample site per plant in September 2001. Dibromochloro- and tribromoacetonitrile—both brominated analogues of the ICR HAN trichloroacetonitrile—were detected at plant 11 in March 2001 by the broadscreen GC/MS methods (Table 12).

*Haloketones.* In addition to the formation of low levels of haloketone (HK) compounds from the ICR (i.e., 1,1-dichloro- and 1,1,1-trichloropropanone), low levels of some of the target study HKs were detected in selected samples from plant 11 and plant 12 (Figure 17). In addition to the formation of the two chlorinated HKs in the ICR, brominated analogues of these two HKs (i.e., 1,1-dibromo- and 1-bromo-1,1-dichloropropanone, respectively) were detected in September 2001 at plant 11, but were not detected at plant 12. In contrast, more of the 1,1,1,3-tetrachloropropanone was formed in September 2001 at plant 12.



Figure 16. September 10, 2001

Effect of Bromide on HAN Speciation at  
Plant 11 ( $\text{Br}^- = 0.21 \text{ mg/L}$ ) and Plant 12 ( $\text{Br}^- = 0.02 \text{ mg/L}$ )

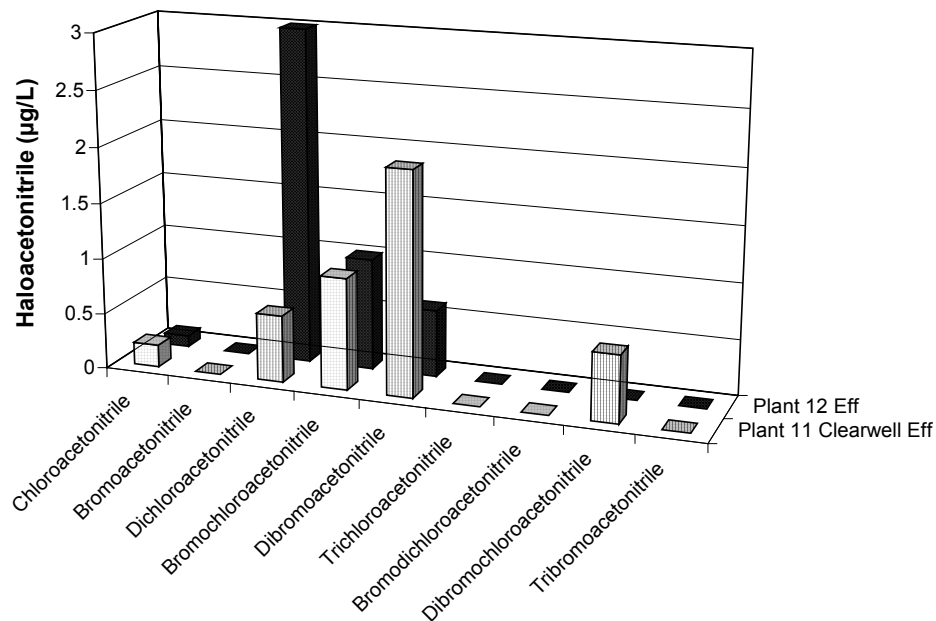


Figure 17. September 10, 2001

Effect of Bromide on HK Speciation in Plant Effluents at  
Plant 11 ( $\text{Br}^- = 0.21 \text{ mg/L}$ ) and Plant 12 ( $\text{Br}^- = 0.02 \text{ mg/L}$ )

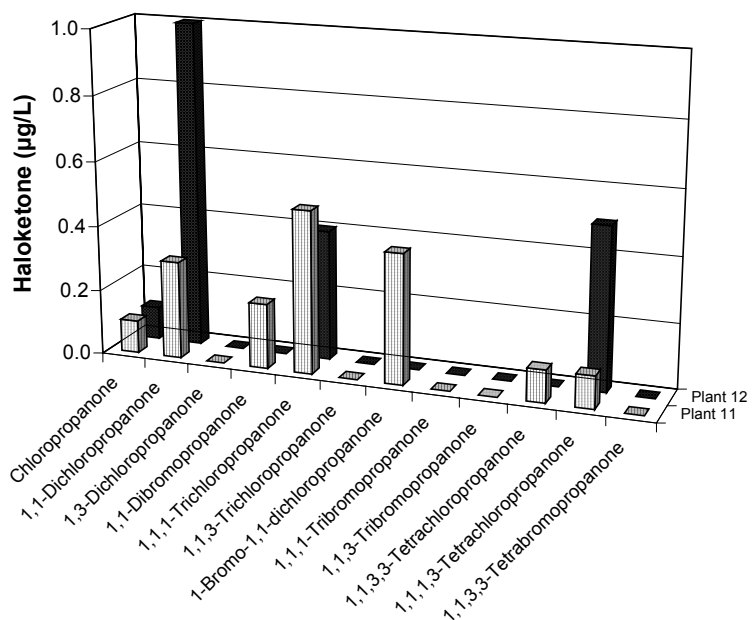
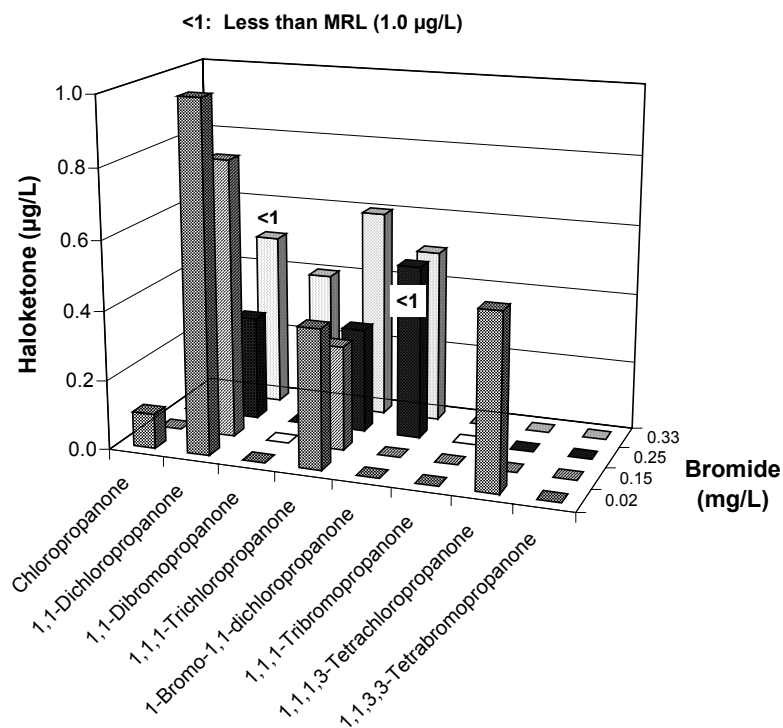


Figure 18 shows the impact of bromide on HK speciation at plant 12. In September 2001, when the bromide level was low (0.02 mg/L), two chlorinated HKs (chloro- and 1,1,1,3-tetrachloropropanone) were detected that were not found in March 2001, November 2001, or February 2002. In March 2001 and February 2002, when the bromide level was high (0.25 and 0.3 mg/L, respectively), two brominated HKs (1,1-bromopropanone [February 2002 only] and 1-bromo-1,1-dichloropropanone) were detected that were not found in September and November 2001 (November bromide = 0.15 mg/L).

**Figure 18. Impact of bromide on HK speciation at plant 12 effluent**



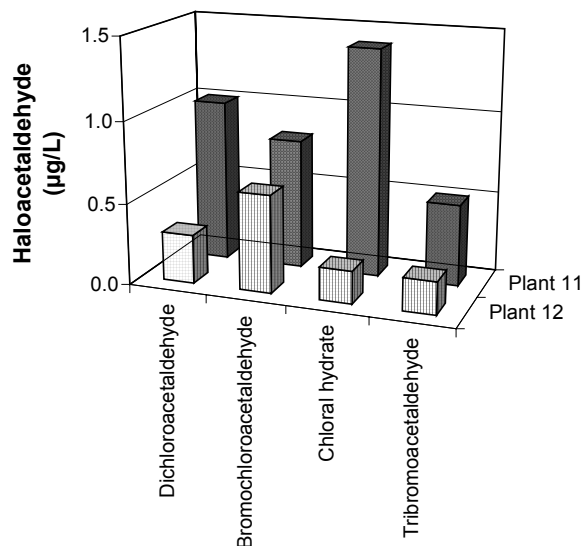
In addition to the target HKs, other HKs were detected by the broadscreen GC/MS methods (Tables 12 and 21). Some of these HKs were analogous to the tri- and tetrahalogenated HKs analyzed by MWDSC, except they were mixed bromochloro species. In addition, another HK that was detected by the broadscreen GC/MS methods at plant 12 was pentachloropropanone (PCP). MWDSC analysts had attempted to include PCP in its target compound list, but it degraded immediately and completely in water under all conditions they evaluated (Gonzalez et al., 2000).

*Haloaldehydes.* In addition to the formation of low levels of chloral hydrate (trichloroacetaldehyde), low levels of target haloacetaldehydes were detected (Figure 19). Both chlorinated and brominated species were formed. In March 2001, the level of chloral hydrate was higher at plant 11. In other research, chloramines were found to minimize the formation of chloral hydrate, whereas certain dihalogenated DBPs were formed to greater extents (Young et al., 1995). Consistent with that research, the formation of dihalogenated acetaldehydes was favored over trihalogenated species at plant 12. Moreover, the relative formation of di- versus

trihalogenated acetaldehydes at both utilities was consistent with the DXAA versus TXAA data at these plants (Figure 20).

**Figure 19. March 26, 2001**

**Effect of Bromide and Disinfection Scheme on Haloacetaldehyde Speciation at Plant 11 (Chlorine Dioxide/Chlorine/Chloramines) and Plant 12 (Chloramines Only) in Distribution System Sample/Maximum Detention Time**



**Figure 20. March 26, 2001**

**Effect of Disinfection Scheme on HAA and Haloacetaldehyde Speciation in Plant Effluents at Plant 11 (Chlorine Dioxide/Chlorine/Chloramines) and Plant 12 (Chloramines Only)**

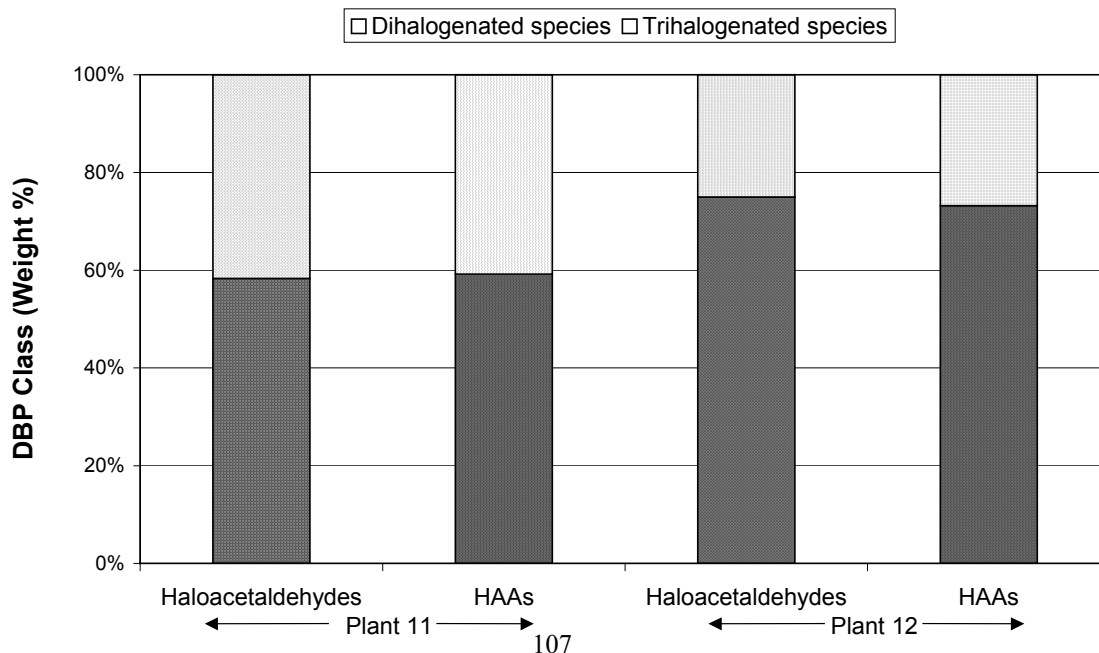


Figure 21 shows seasonal variations in the formation and speciation of haloacetaldehydes at plant 11. In September 2001, there was more of a shift to the brominated species. Also, because of the warmer water temperature in September 2001, there was the greatest haloacetaldehyde formation that month. Because of the colder water temperature in February 2002, there was the lowest haloacetaldehyde formation that month.

**Figure 21. Seasonal formation and speciation of haloacetaldehydes at plant 11 clearwell or plant effluent**

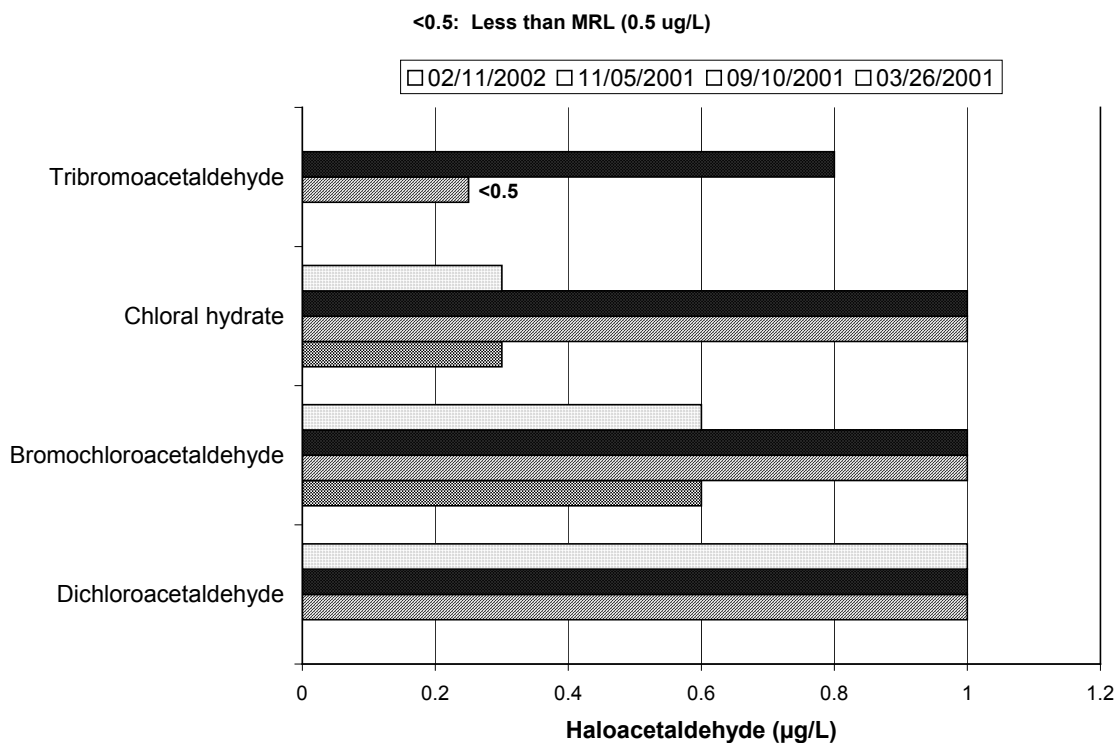


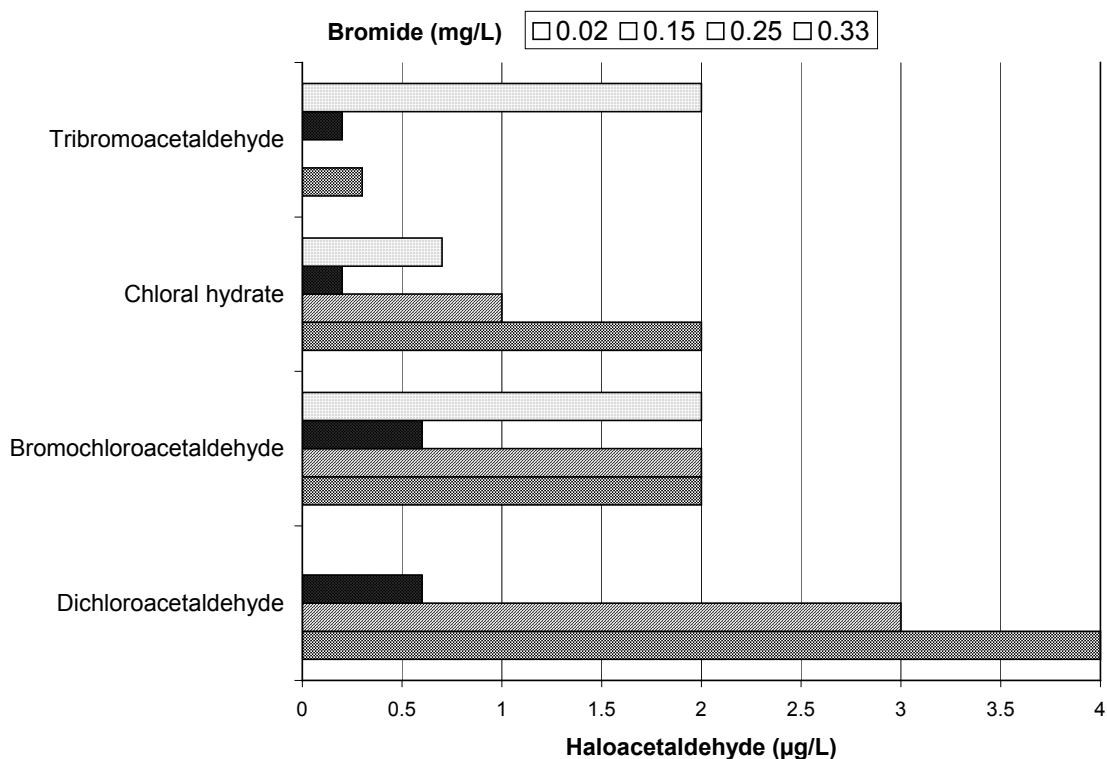
Figure 22 shows the impact of bromide on the formation and speciation of haloacetaldehydes at plant 12. In February 2002, when the level of bromide was the highest (0.33 mg/L), no dichloroacetaldehyde was detected, whereas there was bromochloroacetaldehyde formation. In addition, the formation of chloral hydrate (trichloroacetaldehyde) was low, whereas the formation of tribromoacetaldehyde was high. In March 2001 when the level of bromide was also high (0.25 mg/L), the formation of dichloro- and bromochloroacetaldehyde (both dihalogenated species) were similar and the amounts of the chloral hydrate and tribromoacetaldehyde (both trihalogenated species) were the same. Alternatively, in September 2001 when the level of bromide was low (0.02) or in November 2001 when the level of bromide was moderate (0.15 mg/L), the formation of dichloroacetaldehyde was higher than that of bromochloroacetaldehyde and the formation of chloral hydrate was higher than that of tribromoacetaldehyde. Regardless of the level of bromide, the formation of dihalogenated species was typically favored over trihalogenated species (e.g., dichloroacetaldehyde versus chloral hydrate) at plant 12 (Figure 22). In February 2002 (bromide = 0.33 mg/L),

dichloroacetaldehyde was not detected with an minimum reporting level (MRL) of 0.98 µg/L. As a result, the sum of the dihalogenated species was relatively low that month. In addition, that was the only month in which chlorine dioxide was used during pre-treatment.

In addition to the target haloacetaldehydes, other haloaldehydes were detected by the broadscreen GC/MS methods (Tables 12 and 21). At plant 11, dibromo- and bromodichloroacetaldehyde—which are brominated analogues of dichloroacetaldehyde and chloral hydrate, respectively—were detected. In addition, another brominated aldehyde (2-bromo-2-methylpropanal) was detected at both plants.

*Halonitromethanes.* In March 2001, September 2001, November 2001, and February 2002, sub-µg/L levels of chloropicrin (trichloronitromethane) and other halonitromethanes were detected in selected samples at plant 11 (bromopicrin was detected at 1 µg/L in one sample in February 2002). This included mono-, di-, and trihalogenated species, with and without bromine. Sub-µg/L to low µg/L levels of halonitromethanes were detected at plant 12 in March 2001, September 2001, November 2001, and February 2002.

**Figure 22. Impact of bromide on haloacetaldehyde speciation at plant 12 effluent**



**Figure 23. Haloacetaldehyde speciation at plant 12 effluent**

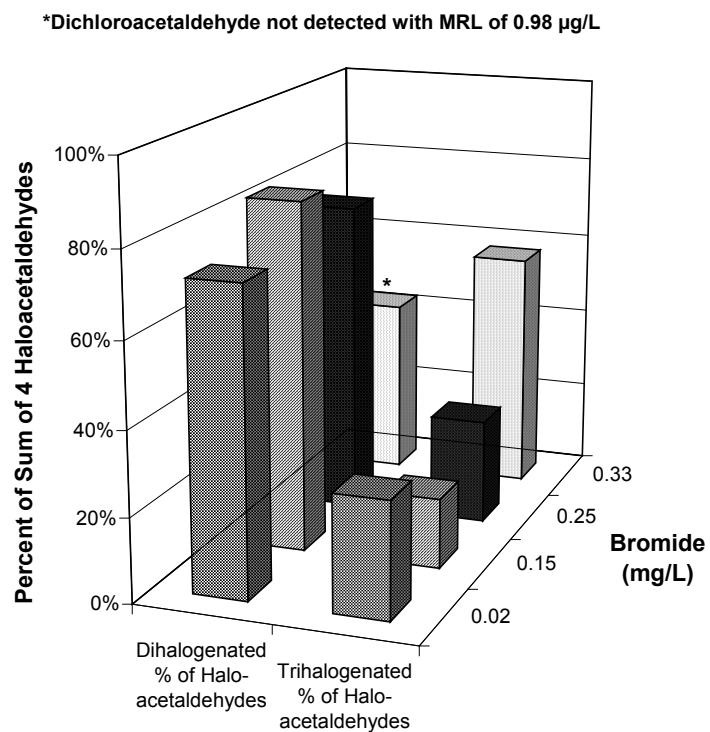
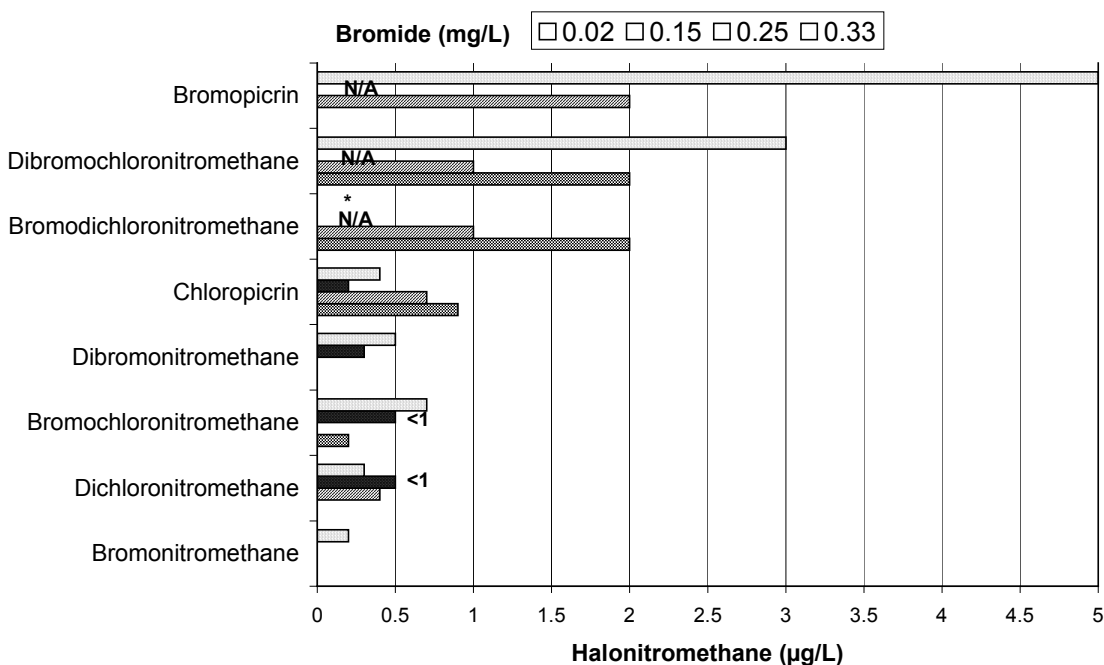


Figure 24 shows the impact of bromide on the speciation of the halonitromethanes at plant 12. As bromide increased, the formation of chloropicrin decreased (from 0.9 down to 0.2-0.4  $\mu\text{g/L}$ ), whereas the formation of the brominated species increased (e.g., bromochloronitromethane formation increased from not detected or 0.2 to 0.7 or  $<1$   $\mu\text{g/L}$ ). In February 2002, when the level of bromide was the highest (0.33 mg/L), bromonitromethane was detected, but not in other months. In addition, dibromonitromethane was only detected in February 2002 and in March 2001 (bromide = 0.25 mg/L). In addition to the formation of chloropicrin, brominated analogues of this trihalogenated nitromethane were detected in the September 2001, November 2001, and February 2002 samples. Data for the brominated trihalogenated nitromethanes were not available (N/A) in the March 2001 samples. Bromopicrin was detected in September 2001 (bromide = 0.02 mg/L) in the filter influent sample, but was not detected in the plant effluent sample, whereas the two mixed bromochloro trihalogenated species were detected in the plant effluent. Alternatively, when bromide was higher (in November 2001 [0.15 mg/L] and February 2002), bromopicrin formation was the highest (2 and 5  $\mu\text{g/L}$ , respectively).

**Figure 24. Impact of bromide on halonitromethane speciation at plant 12 effluent**

<1: Less than MRL (1.0  $\mu\text{g/L}$ ); N/A = Not analyzed in March 2001 when bromide = 0.25 mg/L;  
 \*Bromodichloronitromethane not detected in Feb. 2002 (Br<sup>-</sup> = 0.33 mg/L) with MRL of 2.0  $\mu\text{g/L}$



At plant 11 in September 2001, bromodichloro- and dibromochloronitromethane were detected at or above the MRL of 0.5  $\mu\text{g/L}$  in the SDS sample held for maximum detention time. Although the SDS samples were not kept cold during the prolonged shipping period in September 2001, these results suggest that these compounds may have been present in other plant 11 samples, but at concentrations below the MRL.

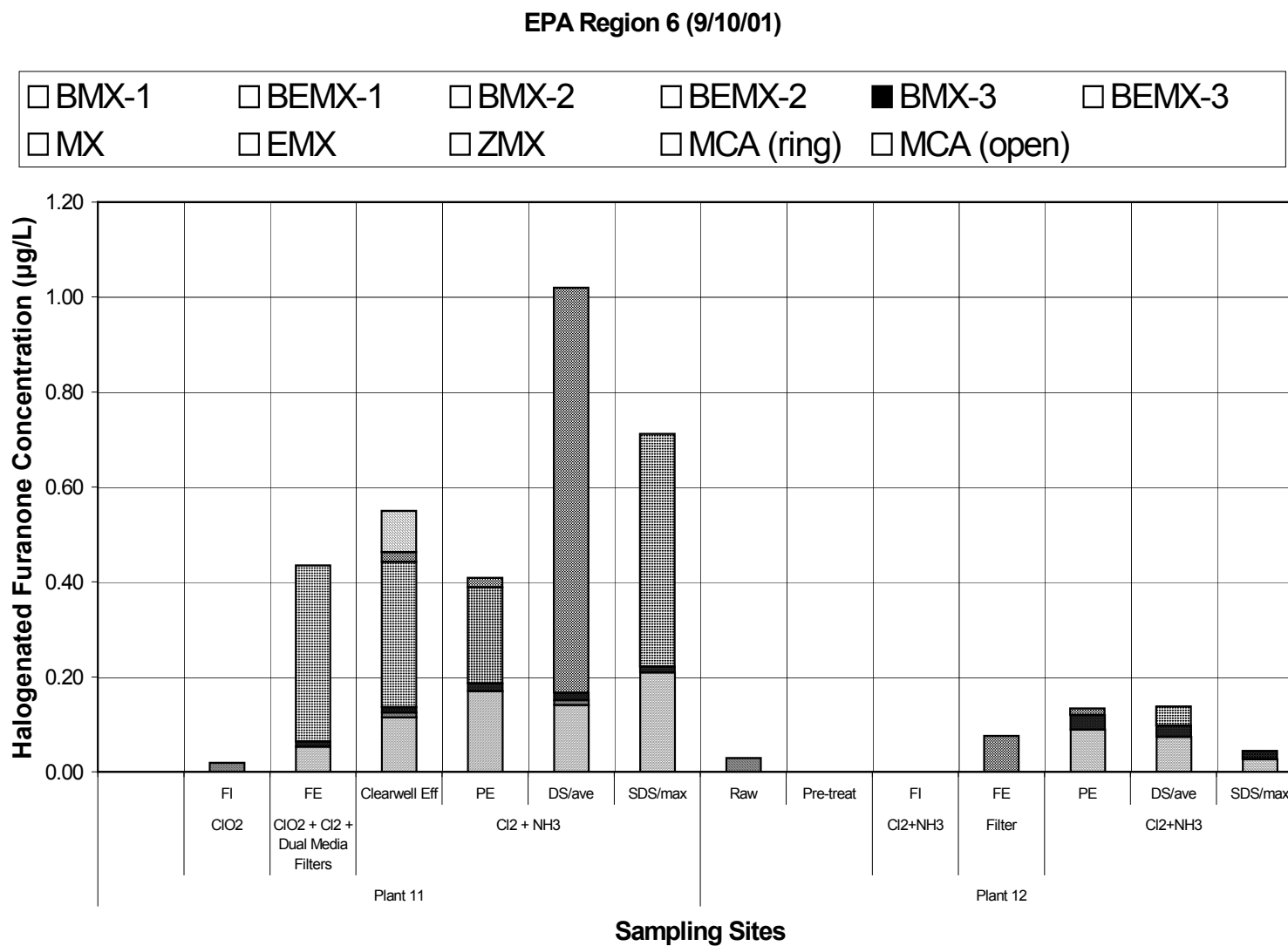
*Halogenated furanones.* Tables 17 and 18 show the results for halogenated furanones in the September 2001 samplings for plants 11 and 12; Tables 26 and 27 show the results for the February 2002 samplings. Data are included for 3-chloro-4-(dichloromethyl)-5-hydroxy-2[5H]-furanone, otherwise known as MX; (E)-2-chloro-3-(dichloromethyl)-4-oxobutenoic acid, otherwise known as EMX; (Z)-2-chloro-3-(dichloromethyl)-4-oxobutenoic acid (ZMX); the oxidized form of MX (Ox-MX); brominated forms of MX and EMX (BMXs and BEMXs); and mucochloric acid (MCA), which can be found as a closed *ring* or in an *open* form. Results are displayed graphically in Figures 25 and 26.

Many sample points were analyzed in the EPA Region 6 plants (9/10/01), clearly showing that ClO<sub>2</sub> at plant 11 did not produce MX and MX-analogues at the filter influent except for 20 ng/L of BEMX-1, and that intermediate chlorination/post-chloramination at plant 11 produced more MX-analogues than chloramines at plant 12. ZMX was detected (90 ng/L) in the plant 11 clearwell effluent, but was not detected in the plant effluent, whereas MX was the same at both sample sites (20 ng/L). Predisinfection with ClO<sub>2</sub> at plant 11 did not appear to effectively remove precursors of MX-analogues as has been observed for predisinfection with ozone for other treatment plants in this study. A significant higher concentration of MX (853 ng/L) was detected in the plant 11 DS/average sample compared to the PE sample (20 ng/L), whereas the BEMX-3 was detected in the PE (200 ng/L) and not in the DS/average sample. The plant 11 SDS/maximum sample (490 ng/L BEMX-3) shows that BEMX-3 was stable under the conditions employed in the SDS test. These results suggest that the DS/average sample may represent a different water than the PE sample, as these samples were not collected to follow a “plug” of water over time (as the SDS test was set up to do). With a bromide concentration of 0.21 mg/L and TOC concentration of 3.5 mg/L, the raw water for plant 11 produced BMX compounds during intermediate chlorination/post-chloramination, as found in the majority of samples (11-490 ng/L) from plant 11. Due to the difference in water quality of the river basin in September 2001 (0.02 mg/L Br- and 7.5 mg/L TOC), which fed plant 12, and the difference in disinfection (chloramines only), substantially less brominated MX-analogues (17-90 ng/L) were produced relative to plant 11. At plant 11, the major production of BMX-analogues occurred in the clearwell influent after intermediate chlorination, whereas at plant 12, it occurred between the filter effluent and plant effluent samples.

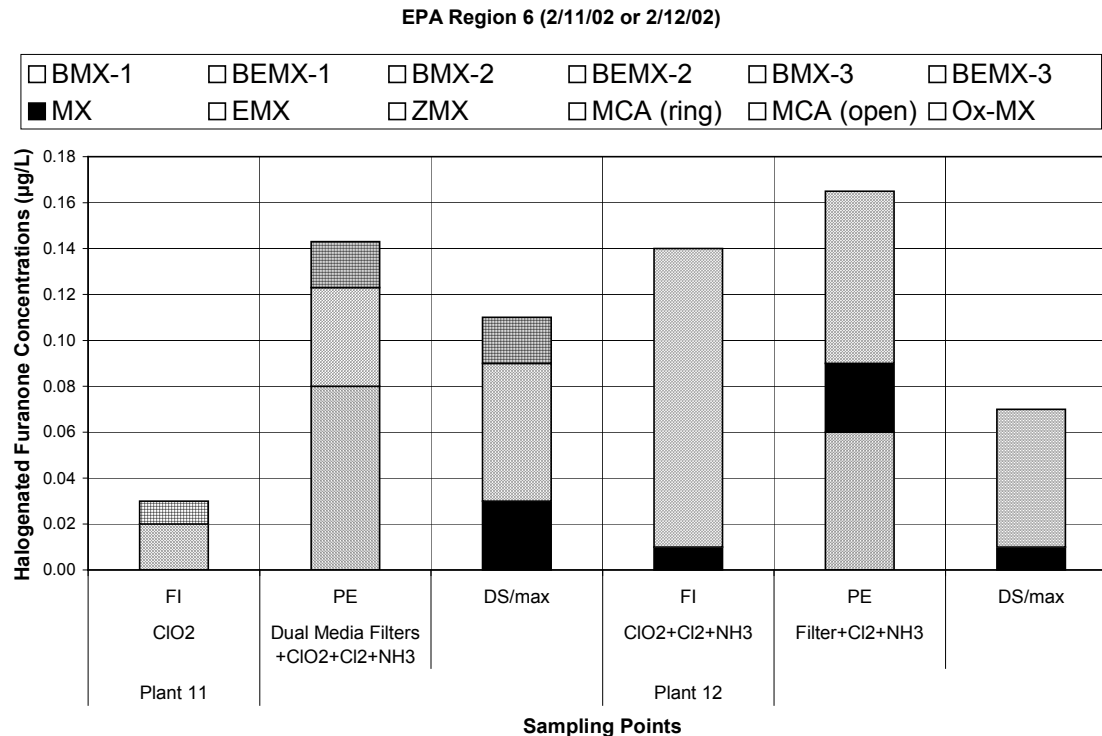
In the second sampling of the EPA Region 6 plants (2/11/02 or 2/12/02) for halogenated furanones, MX and a chlorinated MX-analogue, MCA, were more predominant at plants 11 and 12 than in the earlier sampling (September 2001). One BMX analogue, BMX-1, was also formed at 80 and 60 ng/L in finished waters from plants 11 and 12, respectively, but was not detectable in the DS/maximum samples. The raw water quality of plant 11 was not that different in February 2002 (0.18 mg/L of bromide and 4.3 mg/L of TOC), whereas plant 12's was significantly different (0.33 mg/L bromide and 5.3 mg/L of TOC). In addition, plant 12 used chlorine dioxide during pretreatment in February 2002. These changes in the distribution and occurrence levels of the MX-analogues may be due to changes in raw water quality and operational (treatment/disinfection) parameters from Fall 2001 to Winter 2002.



Figure 25. Halofuranone data at EPA Region 6 plants (9/10/01)



**Figure 26. Halofuranone data at EPA Region 6 plants (2/11/02 or 2/12/02)**



*Other Halogenated DBPs.* In target analyses conducted at UNC, haloamides were frequently identified in finished waters from plants 11 and 12 (Tables 15-16, 24-25). In samples taken in February 2002, all five target haloamides were identified: monochloroacetamide, monobromoacetamide, dichloroacetamide, dibromoacetamide, and trichloroacetamide. Concentrations of individual species ranged from 0.4 to 2.8 µg/L in the plant effluent and were comparable in the distribution system. In September 2001, only one haloacetamide was targeted—dichloroacetamide, which was found at 2.8 and 5.6 µg/L in finished waters from plants 11 and 12, respectively. Haloamides have not been a class of DBPs quantified in potable waters previously. Because the levels observed in these samples are similar to other DBPs that are commonly measured, this may be an important class of DBP that warrants further study.

A few additional halogenated DBPs were identified by broadscreen GC/MS analysis, including dibromoaniline, dibromodichloroaniline, and tribromochloroaniline (plant 12 finished water, November 2001). These compounds were not present in the raw, untreated water.

*Volatile Organic Compounds.* Carbon tetrachloride was detected in two samples at plant 11 (clearwell and plant effluent) in March 2001 at sub-µg/L levels. Carbon tetrachloride is a volatile organic compound (VOC) and a possible DBP. Carbon tetrachloride has been detected by some utilities in gaseous chlorine cylinders (EE&T, 2000). Incidents of carbon tetrachloride contamination of chlorine cylinders have been traced to either imperfections in the manufacturing process or improper cleaning procedures. Carbon tetrachloride is used to clean

out cylinders before filling with chlorine. If carbon tetrachloride is not allowed sufficient time to evaporate, it can contaminate the chlorine.

Methyl ethyl ketone (MEK) was detected in the raw water, in the distribution system, and in SDS testing at plant 11 on September 10, 2001 at a concentration of 0.6-0.7 µg/L. MEK was not detected at or above the MRL of 0.5 µg/L in the clearwell effluent or the plant effluent. MEK was detected at the filter influent and in the distribution system of plant 12 on September 10, 2001 at a concentration of 0.6 µg/L. MEK was not detected at or above the MRL in the raw water or the plant effluent. MEK is an industrial solvent and a possible DBP. At plant 11, its presence in the distribution system was most likely due to its low-level occurrence in the raw water. At plant 12, its occurrence in some samples slightly above the MRL does not allow for a determination as to its origin.

*Non-Halogenated DBPs.* A few non-halogenated DBPs were detected in treated waters from plants 11 and 12 (Tables 15-16, 24-25). The finding of 6-hydroxy-2-hexanone in the filter influent (at 0.8 µg/L) of plant 11 represented one of the few times this DBP was identified in this study (September 2001, Table 15). This compound was likely formed by the initial treatment with chlorine dioxide. 6-Hydroxy-2-hexanone has also been previously reported as an ozone DBP (Richardson et al., 1999). However, although it was initially formed, it was not present in the plant effluent (finished water). Because plant 11 did not use GAC or biofiltration, it was probably not removed by the filtration process. Many ketones can undergo base-catalyzed hydrolysis or can react with chlorine to form secondary by-products. Either phenomenon may be responsible for the loss of this DBP. Another DBP that is typically an ozone DBP—dimethylglyoxal—was also found in the finished water from both plants 11 and 12, generally at levels between 1 and 3 µg/L in the plant effluent. Zhang and colleagues (2000) demonstrated that other disinfectants/oxidants can form carbonyl containing compounds. Broadscreen GC/MS analysis also revealed the presence of acetone and glyoxal in finished water from plant 12 (November 2001), as well as several non-halogenated carboxylic acids in the finished waters, which were at significantly higher concentrations than in the raw, untreated water.

*Distribution System Issues.* Because plant 11 used chloramines in the distribution system, most of the DBPs were found to not increase significantly in concentration in SDS testing (Figure 27) or in the distribution system. Many non-THM DBPs (e.g., dichloroacetonitrile, 1,1,1-trichloropropanone, chloral hydrate) are known to degrade at high pH (Stevens et al., 1989; Croué and Reckhow, 1989). Because the distribution system and SDS testing in March 2001 was only at a pH of 7.4-7.6, most non-THM DBPs were found to be relatively stable (Figure 27).

**Figure 27: March 26, 2001**

**Effect of Simulated Distribution System Testing at Plant 11 on Formation and Stability of DBPs in Chloraminated Water at pH 7.4-7.6**

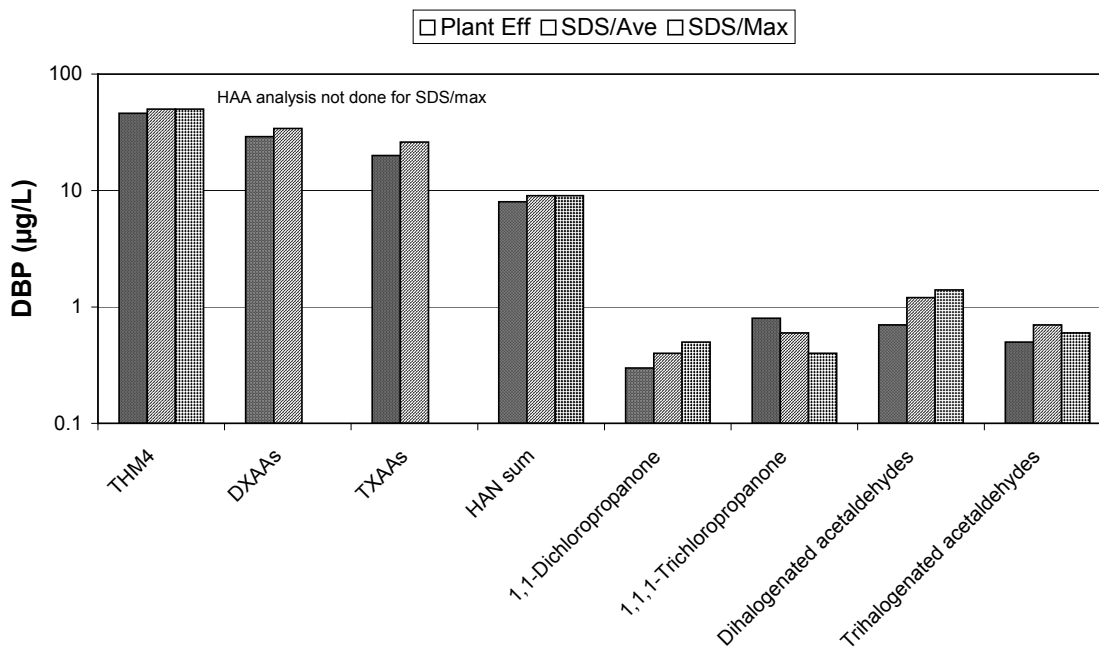
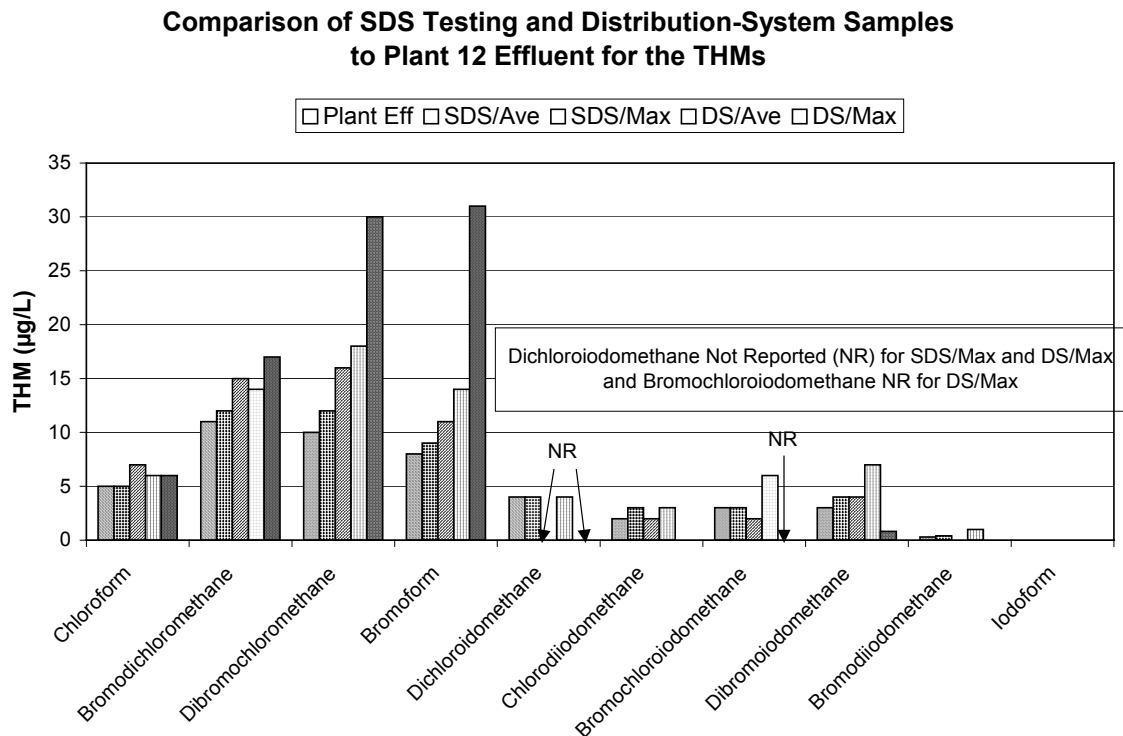


Figure 28 shows a comparison of SDS testing and distribution-systems samples to the plant effluent for the THMs for plant 12 for March 2001. Because plant 12 used chloramines, THMs would not be expected to increase significantly in concentration in the distribution system or in SDS testing. THM4 concentration did increase in the plant 12 SDS testing (from 34 µg/L in the plant effluent to 38 and 49 µg/L in the SDS samples held for average and maximum detention times, respectively). The increase in concentration in the SDS samples (especially at maximum detention time) was primarily due to the formation of the brominated THMs (Figure 28). Other research has shown that THM formation can increase in chloraminated water when an elevated level of bromide is present (Diehl et al., 2000).

Figure 28. March 26, 2001



Alternatively, THM4 was significantly higher in concentration in the plant 12 distribution-system samples in March 2001 (34 µg/L in the plant effluent versus 52 and 84 µg/L in the distribution-system samples collected at average and maximum detention times, respectively). The increase in concentration in the distribution-system samples (especially at maximum detention time) was primarily due to the formation of dibromochloromethane and bromoform (Figure 28). Distribution-system samples can be significantly different than the plant effluent for two reasons:

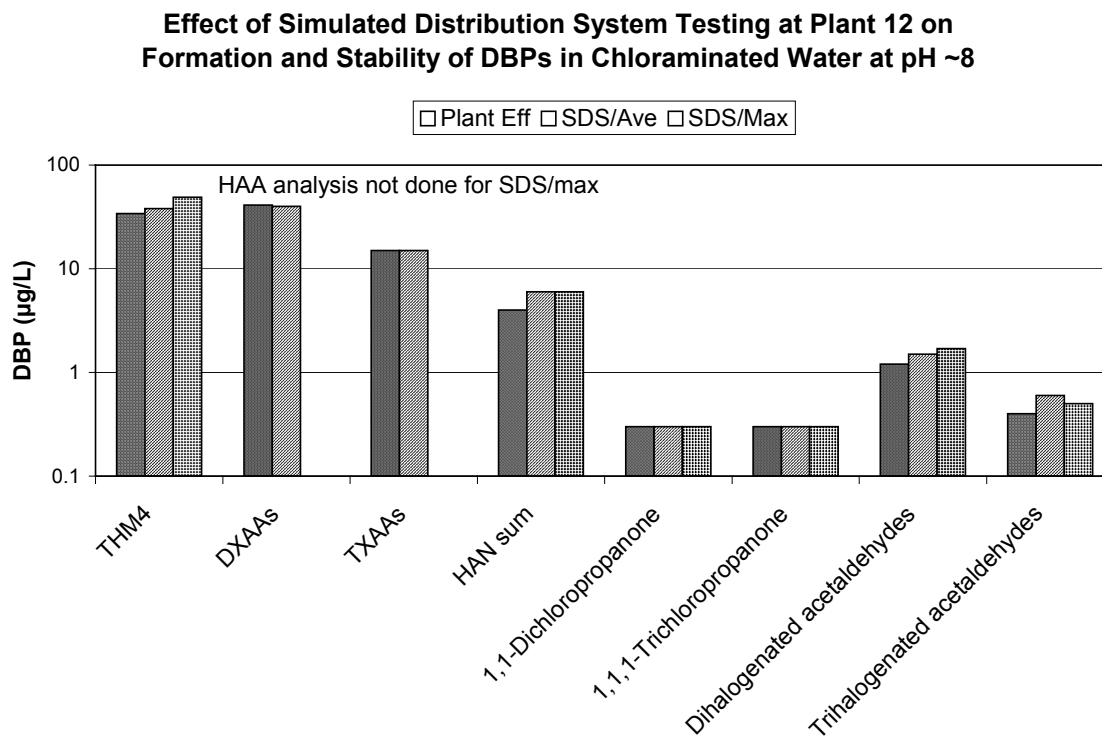
- ◆ One, grab samples for the plant and distribution system were collected on the same day (as requested) rather than following a plug of water over time--i.e., collecting the plant effluent on one day and collecting the distribution-system samples a period of time (e.g., days) later that matched the expected detention time in the system. Thus, the distribution-system samples (especially at maximum detention time) represented water produced at the plant on a different day in which the source-water quality and/or plant operations may have been different.
- ◆ Second, distribution-system samples may not always contain water only from the plant effluent if there are other sources of water that may feed the distribution system (e.g., well water).
- ◆ Thus, distribution-system samples represented the actual occurrence of DBPs, whereas SDS testing allowed for an examination of the effect of detention time on DBP formation without any of the confounding issues associated with distributed water.

In terms of the iodinated THMs at plant 12 in March 2001, SDS results were comparable to the plant effluent data. Alternatively, some of the iodinated THMs (i.e.,

bromochloriodomethane, dibromiodomethane, and bromodiiodomethane) were significantly higher in the distribution system at average detention time as compared to the plant effluent and one of the iodinated THMs (i.e., dibromiodomethane) was significantly lower in the distribution system at maximum detention time (Figure 28). Because a similar increase or decrease in formation was not observed in the SDS testing, this suggests that the distribution-system samples represented a somewhat different source of water than the plant effluent collected on the same day.

Figure 29 shows the effect of SDS testing at plant 12 in March 2001 on the formation and stability of a range of DBPs. Because the SDS testing was only at a pH of ~8, most non-THM DBPs were found to be relatively stable (Figure 29).

**Figure 29. March 26, 2001**



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